STUDY ON SOILS OF SEMI-ARID ECOSYSTEM OF DISTRICT MATHURA, U.P., INDIA, USING STATISTICAL ANALYSIS OF REMOTELY SENSED DATA.

ABSTRACT

Thesis submitted for the degree of

Doctor of Philosophy

IN

REMOTE SENSING APPLICATIONS

BY

S. M. A. RIZVI

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RESOURCE EVALUATION AND GEOENGINEERING
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ABSTRACT

Soil is the backbone of India's agro-economy. The limited arable land contributes about 40 per cent towards Gross National Product (GNP) and provides livelihood to about 70 per cent of the population. It is, therefore, very important to regard the cropland and its soil as a scarce resource, whose protection is essential to meet the most basic needs of mankind that is, agricultural products.

It is a well-known fact that the population expansion will lead to the contraction of arable land in the coming decades which, in turn, may disturb the ecological balance resulting in to the beginning of the process of desertification and hence, a decrease in soil productivity. Further, the extensive use of pesticides, insecticides, and inorganic fertilizers may also change the soil characteristics leading to decrease in soil fertility.

The study area of Mathura district lies between North latitude 27° 17′ to 27° 58′ and East longitude 77° 18′ to 78° 12′ and falls under the Survey of India (SOI) topo-sheet numbers 54E and 54F on 1:250,000 scale and 54E/5, 54E/6, 54E/7, 54E/9, 54E/10, 54E/11, 54E/12, 54E/13, 54E/14, 54E/15, 54E/16 and 54I/2, 54I/3 on 1:50,000 scale. The study area is a part of Indo-Gangetic Alluvial Plain, and the soil of this district are alluvium and argillaceous in nature. The basic framework of the soil development in the study area is constrained by lithological disposition of the geological formation, physical features and landscape pattern. Besides, the disposition of ground water in the aquifer system has controlled the soil profile and in some areas water-logging has contributed to soil degradation by development of holomorphic zones.

The study area covering a geographical area of about 3797 sq. km. with gentle slope from north-west to south-east, is irrigated by tube-

wells, canals and their distributaries, and minors. The Yamuna river is the main river, which flows through the study area and divide the district into two physical units: the eastern and the western tracts.

Physiographically, the general slope of the study area is from north-west to south-east. The maximum elevation is about 178m above MSL near Kotban in Chhata tehsil and the minimum is 171.6m above MSL near Jalesar road, Sadabad tehsil.

The study area lies in the basin of Yamuna river and is more or less plain except for few isolated hillocks on the western part of the area. Large area is subjected to fluvial action up to Mahaban and in its onward course river becomes more closely confined between its bluffs, the strips of cultivable land on either sides growing more narrow and precarious.

Environmentally, the study area lies in the semi-arid ecosystem. The climate of the area is mainly dry, intensely hot during summer and quite cold during winter. The minimum temperature generally ranges from 7°C (January) to 26°C (May) and some times falls up to 1°C in the month of January. The maximum temperature during January is about 23°C while in June it is 45°C.

In July-August heavy precipitation takes place. The average annual rainfall in the area is 586.9mm. The south-western part of the study area receives 550mm rainfall which gradually increases to 700mm in the north-eastern part of the area.

The economy of the district is largely dependent on agriculture resources and animal husbandry.

The soil of the Indo-Gangetic Alluvial plain in the semi-arid ecosystem were studied using remote sensing. Digital and visual interpretation of the remotely sensed data was carried out for mapping the soil in the semi-arid ecosystem of Mathura district, U.P.

The study was aided by in situ spectral measurements using multi-band Radiometer. Ground inputs on the physico-chemical characteristics of soils were collected through field work and laboratory investigation to correlate the physico-chemical properties with the spectral response as an aid in mapping the soils using remotely sensed data.

Earlier, the information on soils were generally collected by conventional methods. However, the traditional system of forecasting of the declining of soil fertility status have several problems such as lack of timely information, variability of data and slow retrieval. The advent of remote sensing techniques through satellite data has become an important tool to study, in detail, the soils vis - a - vis crop and cropping pattern of the country.

The quantitative and qualitative data, which was not previously available, are now currently acquired routinely by the earth orbiting satellites to study the soil in respect of spectral, spatial and temporal variability.

The satellite image, used for visual interpretation was obtained from Landsat-TM. The resolution of TM sensor is 30 meter. The Landsat-TM data pertaining to path-row: 146-041 covers the study area. False colour composite (FCC) print on 1:250,000 scale of May 11, 1989 for the study area was used in conjunction with SOI toposheets for the extraction of information regarding the soils.

Thematic maps have also been prepared to depict the geomorphology, drainage system and geology of the area using the imagery.

The interpreted details and thematic boundaries were transferred on to the prepared base map. The natural and manual features were matched with minor adjustments.

Thus, the physiography-soil units were delineated and preliminary interpreted maps prepared. The sample sites were selected from the delineated units for field checking.

Field survey was carried out in the sample site and the soil maps delineated from the satellite image were corrected on the field after field verification. Soil samples were collected from various locations on the basis of visual variation of soil characteristics and their physico-chemical characteristics for soil have been measured in laboratory.

Soil profiles have been collected from the selected locations in the field and soil morphological characteristics of profiles noted..

A systematic visual interpretation of Landsat-TM image for soil study, using photo elements and ancillary information has led to the preparation of the reconnaissance soil map of the Mathura district. Based upon the image interpretation and ground truth collection including soil sampling and analysis.

Eight soil series in the area have been mapped, which are Kupa soil series (KK), Mahaban soil series (TYK), Mathura khadar soil series (YK), Parkhan soil series (UL), Tarauli janubi soil series (WLL), Kolahar soil series (ELL), Pura soil series (WUL) and Koyal soil series (EUL).

UL series is categorized into two sub-classes: S1 (saline) and S2 (sodic) on the basis of physico-chemical characteristics and their spectral responses. S2 is developed in extreme eastern part of the area and is less in spatial spread, while S1 is scattered mostly along the major canal in the form of irregular patches.

The mapped soil series categorized under land capability class II & land irrigability class II are EUL, WUL, ELL and WLL, while series UL, TYK, KK and YK are categorized under classes III and IV respectively.

It is also observed that there is a correlation between the soil mapping units delineated based on image elements and geomorphic features with the soil characteristics in Mathura district.

Morphologically, the study area shows that the lessivage process is low in 'A' horizon, while it is moderate to high in 'B' and 'C' horizons. This process indicates (a) depletion of clay in 'A' horizon, (b) enrichment of clay in 'B' horizon rather than 'C' and 'A' horizons, and (c) total fine clay ratio in 'B' horizon is higher than 'A' horizon.

Detrimental effect of canal in the area is evident from the fact that the water-table has reached near the surface and rendered the once cultivable or fertile soil completely water-logged. The complete saturation of soil with canal water gives rise to swampy appearance, where the water-table remains a few feet below the ground. This results in high concentration of salts in the soil and thin layer of salt patches on the soil surface were observed on remotely sensed data along the canal. This also leads to accumulation of sodium in the root zone. Moreover, roads and built-up areas also get affected because of wetting in the area. The shallow aquifer zone and well water, too is affected and sometimes is rendered unfit for drinking, for industry and as well as for agriculture.

The digital image processing of IRS-1A LISS-II data of an area covering 512 × 512 pixels of Mathura district was carried out using 'MGE' and 'EASI / PACE' softwares. Various enhancement techniques and supervised as well as unsupervised classification was attempted on this sub-image of Mathura district. The study shows the utility of various enhancement techniques viz., single band analysis, principal component, FCCs, IHS, IHS transformation and filtering image by making some of the features more discernable. Single band image enhancement could provide limited soil information. However, no enhancement technique could provide the enhanced image for all the features. This shows that depending on the area and the feature to be enhanced, different enhancement techniques will have to be used.

The unsupervised classification provides the information on some of the soil series. Due to the spectral intermixing of different soil series, all the soils could not be classified in the unsupervised classification output.

However, saline-sodic soils could be easily identified and within this category, two classes of salinity and sodicity could be identified in the unsupervised classification. The result showed that due to surface cover variability of some of the soil classes were intermixed and hence could not be separated on the supervised colour coded output. It is possible that at a more detailed level of mapping some of the intermixing seen on the supervised output could be separated, leading to the identification of all different soil series.

In order to study, the spectral characteristics of some of the soil of Mathura district, in situ spectral reflectance measurements were done at 10^{-2} decade factor using SAC designed Radiometer (model-041) in four bands similar to IRS 1A LISS-II bands.

Spectral reflectance measurements of surface soil from the different types of saline soil, vegetation cover, tillage practices and grass cover were studied. This study showed that by using in situ measurements three categories of saline-sodic soils and one category of saline soils could be differentiated. The influence of vegetation cover, tillage practice had an influence on the spectral characteristics on soil.

From the above study, it is observed that the remote sensing technique by providing information on spectral reflectance of different soils, will be helpful in soil monitoring and mitigation of soil degradation for sustainable development of agro-ecosystem at grass-root level in the semi-arid environment.

The remote sensing technique, has thus, synergetic approach by providing an overall information on the soils topography and hydrological conditions of the study area in relation to the spectral behaviour. The soils of the semi-arid ecosystem are faced with the problems of the wind erosion and soil salinization and sodication. It is therefore, necessary that proper measures be taken for managing these soils in order to achieve sustainable production and to maintain ecological balance. Remotely sensed data has proved its utility in providing this valuable information for achieving these objectives.

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ALIGARH (INDIA)

1999

DEDICATED

TO

MY PARENTS

DEPARTMENT OF
STATISTICS & OPERATIONS RESEARCH
ALIGARH MUSLIM UNIVERSITY
ALIGARH - 202 002 INDIA

Ref. No. RSACREG/ .... **Dated : ....**

CERTIFICATE

This is to certify that **Mr. S.M.A. Rizvi** has carried out his research work on "**Study on soils of the semi-arid ecosystem of district Mathura, U.P., India, using statistical analysis of remotely sensed data**" under our joint supervision at Remote Sensing Applications Centre for Resource Evaluation and Geoengineering, Aligarh Muslim University, Aligarh. The work is an original contribution to the existing knowledge of the subject.

Mr. Rizvi is allowed to submit his thesis for the award of Ph.D. degree in Remote Sensing Applications.

AN Singh 28/8/99

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(Syed Mohd. Asghar Rizvi)

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CHAPTER-I

INTRODUCTION

INTRODUCTION

1.1 General Statement

Soil is a complex mixture of materials having various physical, chemical and organic properties. The morphological characteristics of soils vary at close intervals and have repetitive patterns in nature and have three-dimensional variability.

Janny [1941] has described the soil formation as

$$S = f\,(cl, o, r, p, t, \ldots\ldots)$$

where	cl	=	climate
	o	=	organism
	r	=	relief
	p	=	parent material
	t	=	time.

Each of the above factors is responsible for the formation of soil. Various soil forming processes active in a specific area further modify the soil development. Owing to these factors and process, an engineer and an agricultural soil scientist each has a different concept of soil and uses a different terminology in describing soils.

Most engineers consider all unconsolidated earth material lying above bedrock to be "soil". Agricultural soil scientists regard "soil" as a material that develops from a geologic parent material through the natural process of weathering and contain a certain amount of organic material and other constituents that supports plant life (Lillesand & Keifer, 1987).

1.2 Soil types of Indo-Gangetic Plain of Uttar Pradesh

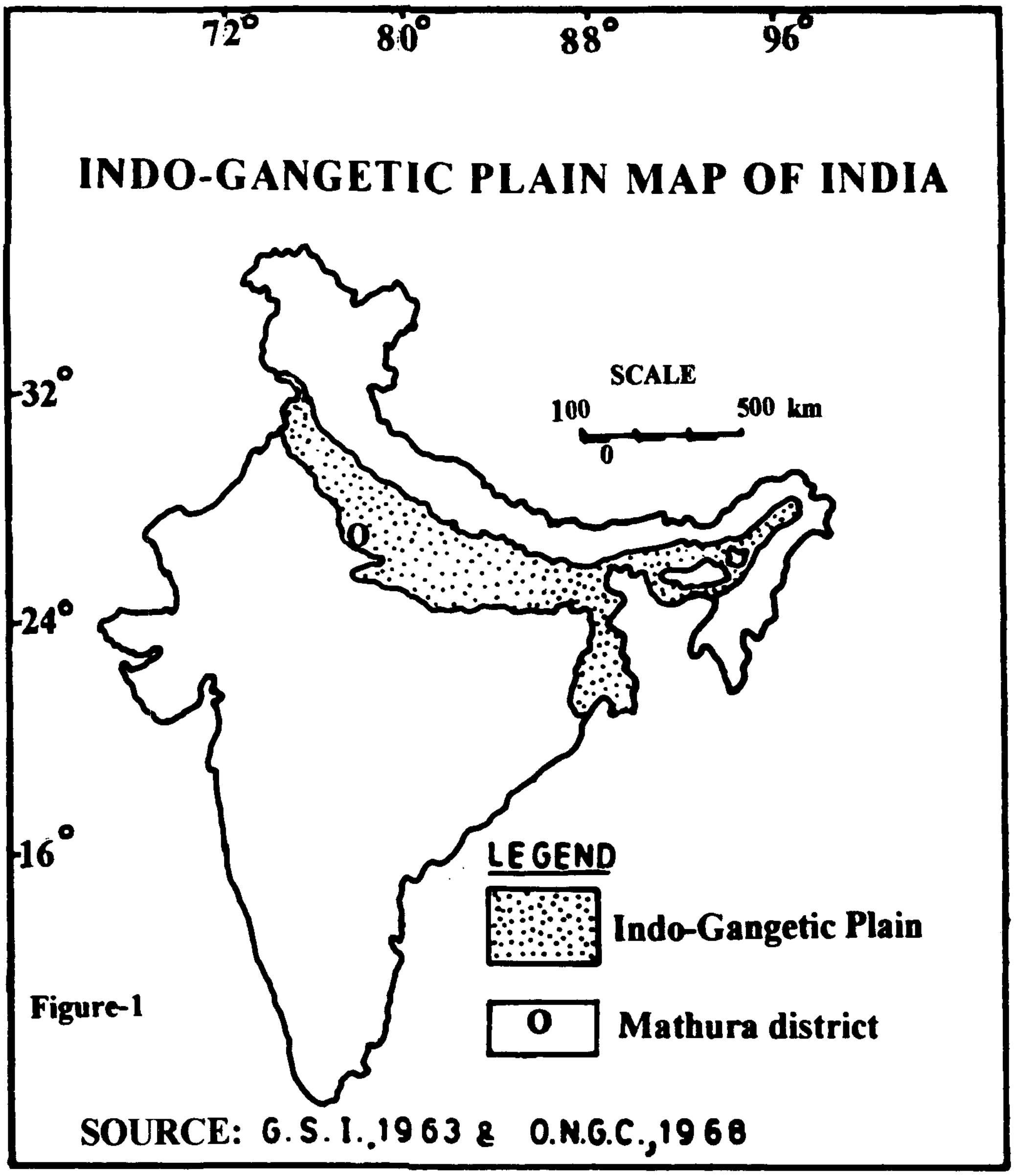
The soil of the Indo-Gangetic plain is alluvial in nature and the sediments consist of sands, silt and clay with infrequent gravel. The soils of this plain are in two groups, the older alluvium (known as *Bhanger* in Ganga Valley) of Middle to Upper Pleistocene period is of darker colour and contains much concretions and nodules of impure calcium carbonate (called *kankar*). This older alluvium occurs on slightly elevated terraces rising above the flood level. The Newer Alluvium Group (also called *Khadar*) of Upper Pleistocene to Recent period, contains beds of silt, clay, sand and gravel lenses. It is relatively light-coloured and less calcareous in nature.

Singh *et. al.*, (1979) have described that the soils in the area have been formed from the material transported by the rivers Ganges and Yamuna. The Ganges river has built up an alluvial cone, the bouldery deposits of which are away from the center and are gradually covered with sub-recent silty and clayey river alluvium. The younger deposits, which are partially flooded during the monsoon, do not show any soil development. The soils developed in the older river alluvium show argillation. Salinization and Alkalization in this alluvial plain have been developed primarily due to natural conditions viz. geomorphology, geology, hydrology, relief and meteorological conditions, and secondarily due to anthropogenic influence by introducing irrigation without adequate drainage. The largest development of salt-affected soil has been found in Indo-Gangetic alluvial plain of which nearly 1.23 million ha. occurs in Uttar Pradesh (Singh *et. al.*, 1989) state.

Geographically, soils of this plain pass through many states of India, such as Uttar Pradesh, Bihar, Punjab, West Bengal, parts of Assam, Orissa and North-East Hill states, etc. (Figure: 1).

1.3 Semi-arid Ecosystem

The arid lands cover about 36 per cent of the globe. The arid lands have been distinguished into hyper-arid, arid and semi-arid environments. The definitions and delimitations of the arid environment have been variously proposed based on the user's requirements. The parameters such as erosion process (Penk, 1894), drainage patterns, (de Martonne and Aufrere, 1927), climate (Koppen, 1931) and vegetation (Shantz, 1956) have been used.



72°
80°
88°
96°
INDO-GANGETIC PLAIN MAP OF INDIA
32°
24°
16°
SCALE
100
500 km
0
LEGEND
Indo-Gangetic Plain
O Mathura district
Figure-1
SOURCE: G.S.I.,1963 & O.N.G.C.,1968

UNESCO has adopted the classification of arid environments proposed by Meigs (1953) which is based on Indices of moisture availability (Im).

$$\text{Im} = \frac{(100\,\text{S} - 60\,\textbf{D})}{\text{PE}}$$

where PE is potential evapotraspiration, calculated from meteorological data, and S and D are, the annual moisture surplus and moisture deficit respectively, aggregated on an annual basis from monthly data, and taking stored soil moisture into account.

Environments: Semi-arid ($-40 \le \text{Im} < -20$); arid ($-56 \le \text{Im}$ -40); and extreme (or hyper) arid ($\text{Im} < -156$).

The Meigs (1953) classification suggests a kindred relationship between hyper-arid, arid and semi-arid environments, which vary with changes in the moisture availability of the soils. In the present study the Mathura district adjacent to the tropical plain ecosystem of Indo-Gangetic plain has been included in the arid fence of the Thar and corresponding to the semi-arid environment.

1.4 Soil of Semi-arid Ecosystem

The soils of semi-arid region are essentially mineral soils, characterized by accumulation of salts of variable solubility. The diagnostic parameters of the semi-arid soils of the district are any one of the following units or their combination.

1. Calcium Carbonate accumulation within 60-100 cm of surface as crust, encrustation, nodules of hydromorphic or authigenic origin.
2. Gypseous accumulation as crust, fibers and powder.
3. Halic soluble salts accumulation.

4. Mixed accumulation of salts of variable solubility i.e. any combination of the above units.

1.5 Remote Sensing in Soil Study

Spectral signatures of the soil surface offer valuable information for mapping and the application of multi-spectral remote sensing in improving accuracy and decreasing the amount of field work in mapping of soil. (Singh, 1982).

Use of the soil forming factors [S = f(cl, o, r, p, t, ...)] through remote sensing data products is the best method to map spatial distribution of soils. Soil is difficult to map directly, but above parameters' relationship govern the soil characteristics. Physiography, which has an interrelationship with soils, can also be mapped through the use of remote sensing data product. The level of sub-division of physiographic units is based on the level of mapping.

Soil study comprises the mapping of natural soil bodies as well as the study of their dynamic aspects. The mapping of natural soil bodies or soil geography is concerned mainly with more or less permanent properties of soil whereas the study of dynamic aspects regards features such as soil temperature, soil moisture, salinity / sodicity and structural changes.

Remote sensing techniques mostly use reflected energy, which shows only a shallow penetration upon interaction with soil. By using this technique, it is possible to obtain direct information about the surface of soil and about vegetation covering the soil. Field survey is necessary to estimate the properties of the three-dimensional soil profile.

Remote sensing images of the surface in the visible and infrared region of the spectrum is most commonly used. However, other parts of the spectrum e.g. ultra-violet, thermal, infrared or microwaves, may also be used for image analysis for studying certain properties of the surface materials such as soil.

1.6 Importance of the Study

Soil is the backbone of country's agro-economy and arable land is limited. The limited arable land contributes about 40 per cent towards Gross National Products (GNP) and provides livelihood to about 70 per cent of the population. It is very important, therefore, to regard cropland and its soil as a scarce resource, whose protection is essential for meeting the most basic needs of mankind.

Due to the above, it is important to utilize the available soil resources by adopting more scientific soil management methods to accelerate food production to meet the need of the country.

The food-grain demand of the country is likely to increase very heavily in the coming decades on account of the increasing human and livestock population pressure. This pressure is disturbing the ecological balance of the fragile ecosystem, resulting into the acceleration of soil degradation and desertification processes.

These processes are reducing limited fertile cropland due to continuous degree of degradation of fertile soil resources from the salinity-sodicity, water-logging, wind erosion / deposition, water erosion, detrimental effect of canals, inorganic pesticide, flood, pollution and other industrial effluents etc.

The information on soils are generally collected by conventional methods, however, traditional system of forecasting declining of soil fertility status have several problems such as, lack of timely information, variability of data and slow retrieval.

In order to understand these problems, a systematic study on soils by employing remotely sensed data is scientifically essential and can act as a pre-requisite for soil study.

Earlier researches show that the conventional methods of soil mapping are tedious, costlier and time consuming. The temporal changes in ecosystem could not be monitored easily. Hence, for collecting reliable information on soil with greater speed and with more accuracy, the remote sensing techniques are being used these days (Singh, *et. at.*, 1977, Venkatraman, 1983, Singh and Dwivedi, 1988).

For the above reasons, systematic studies on soil through remote sensing techniques are required, to get precise and accurate information at the right time to know the spectral behavior of soil, for the purpose of careful planning. Moreover, for management and development of agriculture-based economy, forest, environment and urban settlement etc. also such studies are required.

Further, forecasting and monitoring of desertification of a region is only possible through such studies. This study has focused on the problem of soil degradation and desertification in Mathura district in U.P. state of India. The vacuum in knowledge of the spectral response of soils of the study area through Landsat-TM, IRS 1A LISS II, in situ radiometric measurements have been filled by this study.

1.7 Aims and Objectives

The information on soils of the study area is extremely rudimentary therefore, the objective is to get total coverage of semi-arid ecosystem of Mathura district, U.P. through remote sensing techniques along with ancillary information.

This study on soil is essential for the initial development of soil based agro-ecosystem and agro-economy, its planning, management and in monitoring the effectiveness of agro-ecosystem.

The study through remote sensing techniques for the analysis of soil includes: visual interpretation and digital analysis of remotely sensed data, determining physico-chemical characteristics of soils, and ground based multi-spectral radiometric measurements of spectral behavior of soils.

Keeping the above in view, a study in the semi-arid ecosystem of the Indo-Gangetic Plain, represented by Mathura district, U.P. was conducted with the following objectives.

i) Mapping of soils of Mathura district, U.P. using visual interpretation of satellite data.

ii) To study the utility of digital image enhancement and classification techniques for mapping of soils.

iii) Preparation of spectral reflectance curves of soils in Mathura district through in situ spectral measurements using multi-band field radiometer.

iv) Study of physico-chemical characteristics of soils through laboratory and fieldwork and correlating spectral response with soil characteristics.

CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Mapping of Soils Using Remote Sensing

The study of soil characteristics by aerial photographs was introduced after Second World War, which was an improvement over the traditional methods. Further the availability of satellite data has opened a new source of information to soil scientists.

Black and white panchromatic aerial photographs have been a standard tool for soil resources study and mapping since its introduction in 1929 in the state of Indiana USA (Bushnell, 1951). The photographs increased both the speed and accuracy of soil studies because of the wealth for ground detail shown the accessibility to areas of rugged terrain and three-dimensional view of the soil in the landscape. Soil boundary delineation was possible largely from tonal characteristics with the understanding that the same land area could vary in appearance from one date to another (Bushnell, 1951).

High-altitude photography was found useful in the preparation of medium to small-scale soil maps using soil associations as the delineated unit (Rust, *et. al.*, 1976). The broad synoptic view from high-altitude photographs more nearly corresponded to the level of detail of soil units occurring together in an individual and characteristic pattern over a geographic area. Development of colour aerial films, black and white and colour inferred emulsions, and multi-lens camera systems further expended the possibilities for aerial photographic surveys (Carroll, 1977a). Photo interpretation techniques were not found to be conducive for maximum extraction of tonal information from aerial imagery, which led some authors to suggest the use of instruments to perform this task (Cihlar and Protz, 1972).

Optical-mechanical scanner systems capable for detecting visible, reflective and thermal infrared radiation came into civilian use in the 1960's along with computer pattern recognition techniques for sorting and classifying quantified multi-spectral data (Carroll, 1973 b; Weismiller and Kaminsky, 1978). Preliminary studies of soil mapping using airborne multi-spectral scanner data indicated that soil surface condition could be mapped with reasonable accuracy by computer techniques (Kristof, 1971). Additionally, areas with drainage, run-off, or erosion problems could be mapped in detail. Similar airborne multi-spectral scanner data were used to produce maps showing the locations of five levels of organic matter content in soil (Baumgardner, *et. al.*, 1970). Further studies indicated that clay content in surface soils could be delineated from statistical modelling of multi-spectral scanner data, although it was felt that the relationship between clay content and relative reflectance might be secondary as a result of the high correlation between organic matter and clay content (Al-Abbas, 1972).

Surface reflectance properties of non-vegetated fields as determined from airborne multi-spectral scanner data were found to be sufficient to characterize soil of limestone, shale, sandstone, and local colluvial parent materials (Methews *et. al.*, 1973a).

The data from Landsat satellite became available in 1972. It is collected data in visible and near infrared ranges by multi-spectral scanner from each 0.45 ha. area, within a 34000 km^2 image frame (Baumgardner *et. al.*, 1982).

2.1.1 Visual Interpretation of Satellite Data for Soil Mapping

The first recorded aerial photography in India was flown in 1927 on the 4 inches to a mile scale (Survey of India, 1987).

The use of space borne sensor data in India started in early seventies when Apollo and Gemini space photographs of parts of Uttar Pradesh and Bihar were evaluated for generalized soil mapping by Krishnamurti and Srinivasan (1973a, 1973b). Using monoscopic interpretation of space photo and air photo-interpretation of a part of the area, a small scale soil map was prepared which was found to be better than the existing schematic soil map for that area.

With the launch Landsat-1 in 1972, utilization of its data, both in photographic and digital formats, was initiated by different workers. Mirajkar and Srinivasan (1975) adopted a multi-stage procedure involving visual interpretation of Landsat MSS images supported by air photo-interpretation of sample area for preparation of small scale soil map on 1:1milion scale for parts of Karnataka, Maharashtra and Andhra Pradesh. The resulting soil map was found to be superior to the existing soil map of the area.

The launching of earth resources technology satellite (ERTS-1, later renamed Landsat-1) in July 1972 presented new possibilities and challenges in soil mapping.

Certain unique characteristics of Landsat imagery were recognized as advantageous in low intensity soil surveys for delineation of soil association boundaries (Westin and Frazee, 1976). Among these advantages were: i) the synoptic view of almost 3.4 million ha. on which the condition of soils and stage of vegetative growth were recorded at the same moment; ii) the near-orthographic character of the scenes; iii) the temporal aspect, allowing study of multi-spectral changes in soil / vegetation complex with time. Landsat scene mosaics at the scale of 1:1 million were found useful as base maps for publishing thematic soil maps. Using only visual image interpretation of simulated infrared and individual black and white band imagery soil association maps of single country and entire state have been prepared in USA (Steinhardt *et. al.*, 1975). A South Dakota soil association map of $0.2 / ha. (Westin and Frazee, 1976).

A study carried out on spectral responses in Clinton country Indiana, showed the drainage characteristics to be readily identified through Landsat data analysis. Inclusions and locations of different soils within a map unit could also be mapped which could aid in the map unit evaluation (Kirschner *et. al.*, 1977). Prior to this, conventional soil maps were generally used for checking the accuracy of Landsat based soil maps. This research revealed the reason for previous discrepancies was due to the quantitative nature of the satellite resolution element and the subjective nature of conventional mapping techniques (Kamisky *et. al.*, 1979).

Hilwig (1976) used visual interpretation of Landsat data of a part of Indo-Gangetic plains. Delineation of major physiographic units on Landsat image and ground data from air photo-interpretation map helped in the preparation of fairly accurate small scale soil map on 1: 250,000 scale.

Hilwig (1980) utilized the multi temporal capability of satellite data for inventorying natural resources in a part of Himalayas and adjoining planes of Uttar Pradesh. The dynamic elements such as drainage conditions as reflected by moisture status, vegetation and agricultural land use were integrated with static elements like drainage pattern, alignment and landform for the final physiographic analysis. The multi-temporal and multi-spectral capability of Landsat image proved advantageous in the physiographic-soil survey in the area.

The use of Landsat data in large area project surveys was reported by the National Remote Sensing Agency (NRSA). The project surveys carried out by NRSA in the North-Eastern region of the country (NRSA, 1977a), Karnataka (NRSA, 1978a) and Uttar Pradesh (NRSA, 1980) utilized visual interpretation of Landsat MSS imagery in conjunction with ancillary data and ground truth collection. The mapping was carried out based on physiography-soil relationship. Associations of sub-groups were mapped on 1:250,000 scale. Comparison of soil maps prepared by Landsat data in some of these surveys with the reconnaissance soil maps prepared by conventional methods showed that more accurate maps in terms of boundary delineation and composition of soil mapping units could be made by Landsat image interpretation (Singh, 1980; Singh and Dwivedi, 1986).

In the early 1980s, the use of Landsat data for soil mapping spread too many organizations in the country, like All India Soil and Land Use Survey, Center of Studies in Resources Engineering, Central Arid Zone

Research Institute, Haryana Agricultural University, etc. (Singh *et. al.*,1983). The mid 1980s, however, saw a major break-through in the use of Landsat data when the National Bureau of Soil Survey and Land use Planning decided to prepared the soil map of the entire country on 1:1 million and 1:250,000 scales using Landsat data as base (NBSS and LUP, 1986). Subsequently, NRSA also undertook a project to prepare a salt-affected soil map of India using Landsat data on 1:250, scale.

Preparation of maps on scales larger than 1:250,000, however, started only recently when Landsat TM data enlargements on 1:50,000 scale were first used in preparation of wasteland maps in 146 districts of the country in a project sponsored by the National Wasteland Development Board (Narayna *et. al.*, 1989). Thirteen wasteland categories were mapped including salt-affected wastelands, gullied and / or revinous wastelands, waterlogged and marshy wastelands, undulating uplands, sands, rocky and stony wastelands, etc.

Delineation of soil drainage within parent material areas indicated the soil series present within a given area and provided information about areas not easily accessible or covered with dense crop vegetation. The use of the analysis techniques adopted was supposed to contribute in decreasing the time and cost of country soil survey.

The launch of the Indian Remote Sensing Settalite-1A (IRS-1A) on 17 March 1988 with two sensors-LISS-I and LISS-II having 72.55 and 36.25m resolution, respectively, marked the beginning of the Indian capability in building operational remote sensing satellite. IRS sensors collect data in four spectral lands in the visible and near IR range. Studies carried out in Orissa, Karnataka, and South Tripura showed that LISS-I data is comparable with Landsat MSS and LISS-II comparable with Landsat TM for soil mapping (NNRMS, 1989). Karale and Sinha (1990) observed that IRS-IA based soil maps in a part of Nagpur district, Maharashtra, were comparable to that of the existing soil maps of the area generated by conventional techniques. Additional soil units could also be delineated on computer enhanced IRS-1A image.

2.1.2 Digital Classification of Satellite Data for Mapping Soils

The computer-aided interpretation of Landsat data for soil mapping in the country was initiated at NRSA in their project surveys in the state of Nagaland (NRSA, 1977b), Andhra Pradesh (NRSA, 1978b) and Tamilnadu (NRSA, 1979). Maps prepared by digital analysis of Landsat data in some of these surveys were found to be comparable with the soil map prepared by conventional methods at the same scale (Venkataratnam and Rao, 1977; Venkataratnam, 1981).

The classification accuracy of soil maps prepared using black and white Landsat MSS imagery vis-à-vis air photo-interpretation has been tested by Reddy (1987) in a part of Karimnagar district, Andhra Pradesh. The overall classification performance of 1:250,000 scale Landsat based maps ranged from 30 to 93 per cent in different landscapes, with the combined overall performance of 53 per cent.

Digital analysis of spectral data from these new sensors could classify a landscape scene into many spectrally separable categories on the basic of very subtle differences in one or more of the spectral bands. One of the major problems for the soil scientists in using digital image data is to define quantitatively the spectral characteristics of soils under a wide range of environmental conditions. New instruments are available to conduct research to explain reflectance variation of soils (Stoner *et. al.*, 1980).

Application of image enhancement techniques like colour, slicing, ratioing, ratio-stretching, and contrast stretching on Landsat data help in interpretation and increase the accuracy of soil mapping.

Ali (1993) has developed new statistical methods for analyzing non-normal remotely sensed data. These methods have increased the accuracy of classification of an image and consequently made the use of remotely sensed data more dependable.

2.2 Spectral Characteristics of Soils

In all the early soil studies with multi-spectral scanner data, whether from air or space-borne platforms, researchers faced the dilemma of not being able to understand or explain the causes of many of the variations in reflectance from surface soils.

Visible soil reflectance, or colour, is an essential part of the definition of certain diagnostic horizons in modern comprehensive soil classification (USDA, Soil Survey Staff, 1975).

Soil reflectance is a cumulative property, which derives from inherent spectral behaviour of the heterogeneous combination of mineral, organic and fluid matter that comprises mineral soils. Numerous studies have described the relative contributions of soil parameters such as organic matter, soil moisture, particle size distributions, soil structure, iron oxide content, soil mineralogy and parent material to reflectance of naturally occurring soils (Obukhov and Orlov 1964; Bowers and Hanks 1965; Baumgardner *et. al.*, 1970; Planet 1970; Montgometry 1976; Stoner 1979; Singh *et. al.*, 1979; Dwivedi *et. al.*, 1981).

Extensive literature exists describing the variation in visible and near infra-red reflectance of minerals and rocks (Hunt and Ross 1967; Hunt and Salisbury 1970, 71, 76a & b; Hunt *et. al.*, 1971a & b 1973a & b, 1974).

Under laboratory conditions, Stoner and Baumgardner (1980) studied the bidirectional reflectance factor and physico-chemical properties of over 500 soils from USA, Brazil and Spain. Based on the reflectance characteristics, five general types of soil reflectance curves were identified depending primarily on the presence or its absence of ferric iron absorption bands, organic matter content and soil drainage characteristics. Reflectance in 10 bands across the spectrum was found to be negatively correlated with the natural log of organic matter content. Regression models showed that site characteristics such as climate, parent material, and drainage are important variables along with organic matter, moisture content, texture, and iron oxide content in explaining reflectance differences.

Thompson and Henderson (1984a) evaluated TM data for detecting soil properties under grassland vegetation and found that montmorillonitic clay textured soils could be separated from soils with different textures.

Thompson *et. al.*, (1984) showed that TM with its additional and narrower bands and improved spatial and radiometric resolution can detect variability due to soils within fields of corn and soyabeans. They also observed that the mid-IR and thermal bands show the capability for separating vegetated soil landscape on a broad basis.

Measurement of spectral reflectance of soil using hand held radiometers in the wavelength bands similar to Landsat MSS has also been attempted for some major soil groups of India. Dwivedi *et. al.*, (1980) studied the spectral reflectance pattern of some red, black, and alluvial soils of Uttar Pradesh and the influence of tillage and cover types on it. They observed an increase in per cent spectral reflectance with increasing wavelengths and found that black soils exhibited lower reflectance as compared to red and alluvial soils. Ploughed and exposed soils had lower reflectance as compared to disturbed soils. Increased grass cover increases the reflectance of soils.

The influence of soil moisture, organic matter and particle size on the reflectance of alluvial, black cotton, and lateritic soils have been by Sinha (1987). Soil moisture and organic matter were found to have negative correlation with reflectance. Reflectance of lateritic soils increased with decrease in particle size.

Radiometric study on spectral reflectance of Indian soils in the mid-IR bands compatible to Landsat-TM however, has nor been reported so far.

Spectral response of some typical Indian soils have been studied by Dwivedi *et. al.*,(1981). These authors have given spectral response of normal and sandy soils using field Radiometer Exotech-100A. Further they have also discussed the spectral response for the soils affected by tillage and various cover types. Rao *et. al.*,(1995) have studied spectral response of salt-affected soils again using Exotech-100 Bx Radiometer. In addition to in situ response the authors have also given the spectral response for a TM image. The study area selected by the authors was Indo-Gangetic alluvial plain of Karnal in Haryana state of India.

The physico-chemical characteristics of soils have been studied and soils were further categorized by spectral reflectance behaviour using satellite images (Singh *et. al.*, 1989; Rao *et. al.*, 1991; Dwivedi 1992).

It has been shown by Singh and Dwivedi, (1989) that spectral response-curves exhibit the spectral separability of two salt-affected soil categories: Typic Natrustalfs and the association of Typic Natraquqlfs and Aquic Natrustalfs.

Dwivedi and Rao, (1992) found the band combinations 1, 2, 5, to be best amongst all the Landsat-TM bands for delineating salt-affected soils. This combination ranked first in terms of optimum index factor (OIF) values as well as the accuracy of mapping salt-affected soils.

2.3 Soil Salinization and Alkalization in Semi-arid environment

Salinization is considered as a process of accumulation of soluble salts in the soil whereas, alkalization is a process of increase of the exchangeable sodium of the soil.

Salinization is more commonly found in arid or semi-arid regions than humid areas of the world. This difference is partially justified in terms of more pronounced downward movement of soluble salts encountered in humid regions. Where the rates of evaporation are much lower than those of arid climates. High evaporation combined with low rainfall tend to concentrate the salts near the surface. Furthermore, unfavorable soil conditions created, for instance, by a claypan or a silica hardpan might prevent adequate downward movement of water. In certain cases, the presence of an impermeable soil layer is essential for the formation of saline soils (De Sigmond, 1924). In more recent time, the development of irrigated agriculture has brought about an increase in salinization problems, mainly due to extensive use of water and insufficient drainage or both. This situation has been observed in Mexico, the western U.S. and India where a substantial expansion of irrigation projects has also generated an increase in the salinization (USDA-Handbook No. 60)

In alkalization the surface of soil particles carries electrical charge of cations. This is essentially a surface phenomenon; it involves preliminary the clay, organic and fine silt fractions of soils. The combination of soil particles, water and cations create a closely run environment in which cations like calcium and magnesium may be removed from their adsorbed position on the soil particle and replaced by other cations like sodium. These cations of the combination are readily exchangeable while others are more difficult to be exchanged as they are rather tightly fixed on the soil particles. The ease with which the absorbed cations are freely interchanged with those soils in the solution determines their respective concentrations both on the soil particles and soil solution. When environmental conditions such as higher evaporation in arid regions coupled with the upward capillary movement of water takes place it forces the precipitation of calcium and magnesium compound and sodium tends to become the predominant cation not only in the soil solution but also in the upper horizons and surfaces of the soil. If the excess of soluble salts are mostly chlorides and sulphates of sodium, such soils are sometimes called "white alkali"; on the other hand, extreme cases of alkalinity resulting from the presence of sodium carbonates (Na_2CO_3) commonly show a discolouration of the soil surface provoked by the dispersed humus transported upward by capillary water movement. This soil is often named "black alkali" (Brady, 1984).

The classification of salt-affected soils is essentially based on the soluble salt content and the exchangeable sodium of the exchange site (Pierre *et. al.*, 1982). The chemical and physical characteristics of these soils determine their classification as saline non-sodic, non-saline-sodic and saline sodic. These soils are also referred to, in the literature as saline, saline-alkali and non-saline-alkali, respectively. These groupings are derived from the measurement of pH, the electrical conductivity of the saturation extract at 25°C and the exchangeable- sodium percentage (USDA Handbook No. 60). An over-view of the essential differences in physico-chemical features among these three classes of salt-affected soils are provided in Tables: 1, 2 & 3.

In the recent past, several geo-scientists have attempted to classify / identify and map the saline-sodic soils using remotely sensed data acquired from Landsat (TM and MSS), IRS-IA and IB (Singh *et. al.*, 1977; Venkataratnam, 1983; Singh and Dwivedi, 1989).

Dwivedi *et. al.*, (1981) have found that Exotech Radiometer (Model 100 A and Bx) have shown great promise in separating different soils using spectral reflectance data.

A attempts have been made to group the salt-affected soils according to degree of salinity / sodicity based on (1) areal extent of salt-affected soil in relation to normal soils, (2) chemical characteristics: pH, EC, anions, cations, sodium saturation percentage, and (3) crop response (Agarwal *et. al.*, 1982). Soil with pH above 8.5 have been rated as alkaline or sodic and further sub-division into alkali classes: class 0, 1, 2 & 3 were made on the basis of areal distribution (USDA, 1966).

Beck (1975); Bowers and Hanks (1965); and Montgomery (1976) have described that a variety of soil parameters and conditions, either individual or in association with each other, contributes to the spectral reflectance pattern of the soils. These parameters are: the physico-chemical properties: such as organic matter, moisture, colour, texture & iron oxide content, etc.

The conditions which affects the spectral response of soils in their natural state are green vegetation, shadows, surface roughness and non-soil residue. All of these vary according to tillage operations, cropping system, or naturally occurring plant species (Cipra *et. al.*, 1971; Silva *et. al.*, 1971 and Gausman *et. al.*, 1975, 1976 & 1977). Beside these terrain conditions, total intensity of light energy impinging upon the earth's surface also modifies the spectral response of the soil. The scientific studies carried out on salt-affected soils revealed an increasing trend in the intensity of reflected energy with an increasing sun elevation (Singh, 1982).

Table 1. Summary of criteria for classification of salt-affected soils by Pierre *et. al.*, (1982).

EXCHANGEABLE Na	Electrical Conductivity (mmhos/cm)	
	< 4	>4
<15	Normal (Non-saline/Non-sodic)	Saline Salinenon-sodic (pH<8.5)
15 >15	Non-saline-alkaline (pH>8.5)	Saline-alkaline Saline-sodic (pH>8.5)

Table - 2 Interpretation of the Soil Salinity Status (Buringh, 1979).

Salinity	ECe 10^3	TSS (%)
Salt-free	0-2	< 0.15
Slightly saline	2-8	0.15-0.35
Moderately saline	8-15	0.35-0.65
Strongly saline	> 15	> 0.65

Table 3 Categories of Salt-affected Soils and their Characteristics

Soil Categories	pH	EC in dSm^{-1}	ESP
Saline	< 8.5	> 4.0	< 15
Sodic	> 8.5	< 4.0	> 15
Saline Sodic	> 8.5	> 4.0	> 15

The problem of salt-affected soil is world wide; manifesting in arid, semi-arid as well as humid climate, and in geological formation of all ages from Archean to Recent. The global percentage of salt-affected soil is about 7 per cent by area on land (Szabolcs, 1981). In India, approximately 7000,000 ha. of land area is reported as having saline and sodic soils of which nearly 1.23 million ha. occur in Uttar Pradesh. A major portion of this area lies in the Ganges plains (Singh *et. al.*, 1979; Singh, 1990 and 1994). Mapping of these soils in some states of the plains has been carried out recently using satellite data (NRSA 1981, Singh and Dwivedi 1989, Rao *et. al.*, 1991; Anon., 1994, 1995). The problem is most acute in the alluvial tracts of Indo-Gangetic plain.

CHAPTER-III

STUDY AREA

STUDY AREA

3.1 General Statement

The area under study, Mathura District, is a part of Indo-Gangetic alluvial plain. The Ganga-Yamuna interfluve, palaeo-channel, oxbow lakes, constitutes the major physiographic units, except few isolated hillocks on the western part of the district. Which represent geomorphologically the eastern frontier of the semi-arid ecosystem of Thar desert.

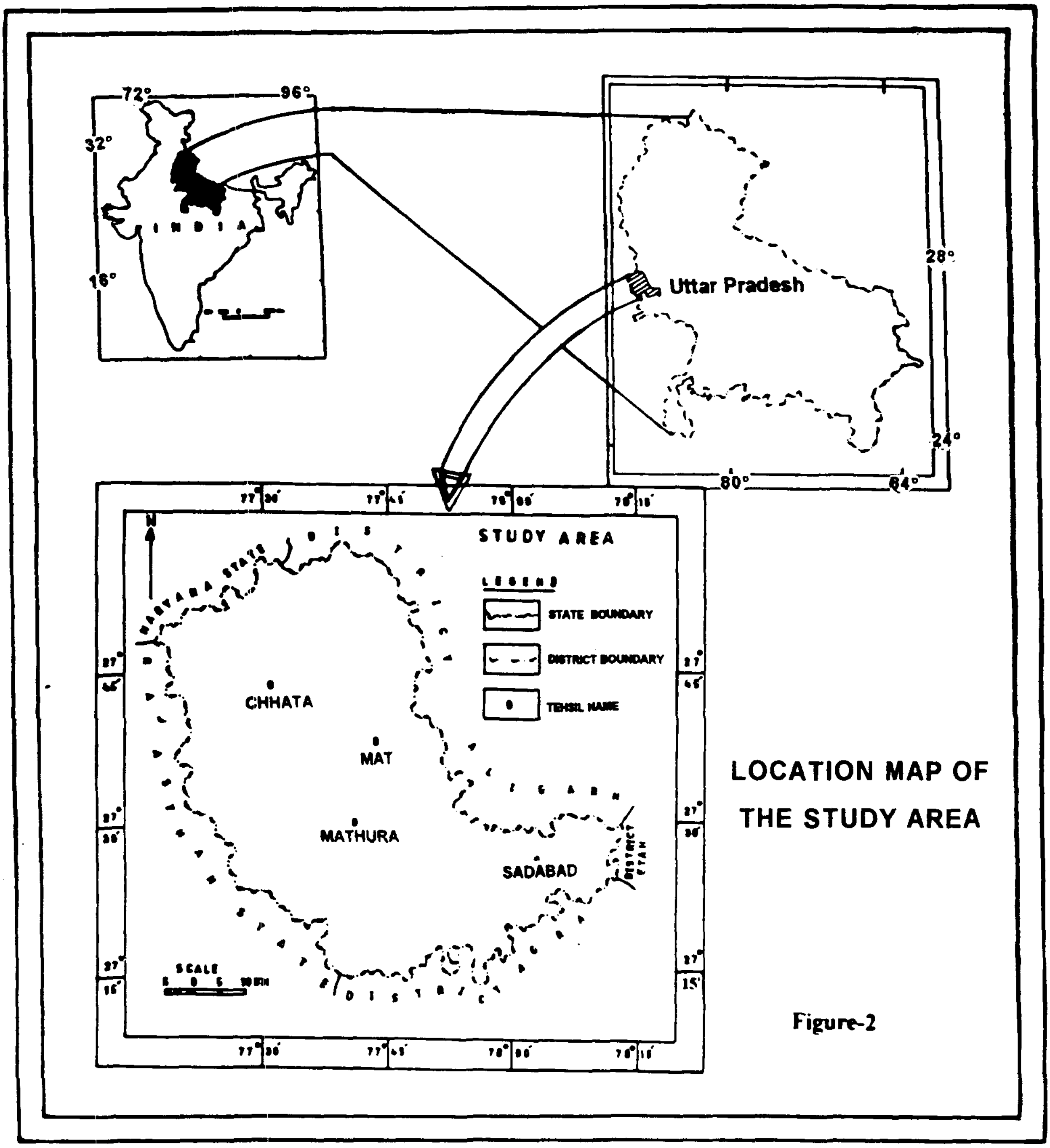
The soils of the district are alluvium and agrillacious in nature. The basic framework for the soil development in the district is constrained by lithological disposition of the geological formation, physical features and landscape pattern. Besides, the disposition of groundwater in the aquifer system has controlled the soil profile and in some areas, water-logging has contributed to soil degradation by development of holomorphic zones in semi-arid ecosystem. The soil moisture condition and the temperature regime come under Ustic and Hyperthermic family respectively.

The study area is irrigated by tube-wells, canals and their distributaries, and minor etc. Covering a geographical area of about 3797km^2 with gentle slope from north-west to south-east. Its lengthiest section is about 96 km. and its greatest breadth about 66 km. (Figure-2) from the west to east (Census, 1981).

The Yamuna is the main river, which flows through the district and divided the district into two physical units: the eastern and the western tracts. The district comprises four tehsils: Chhata, Mathura, Mat, and Sadabad (Figure-2) The district has 1020 village (Census, 1981).

The district is quite well connected by roads and railways. It is situated on main lines of Delhi-Agra-Bombay section of the central railway (broad gauge).

The economy of the district largely depends on agriculture resources and animal husbandry.



LOCATION MAP OF THE STUDY AREA

Figure-2

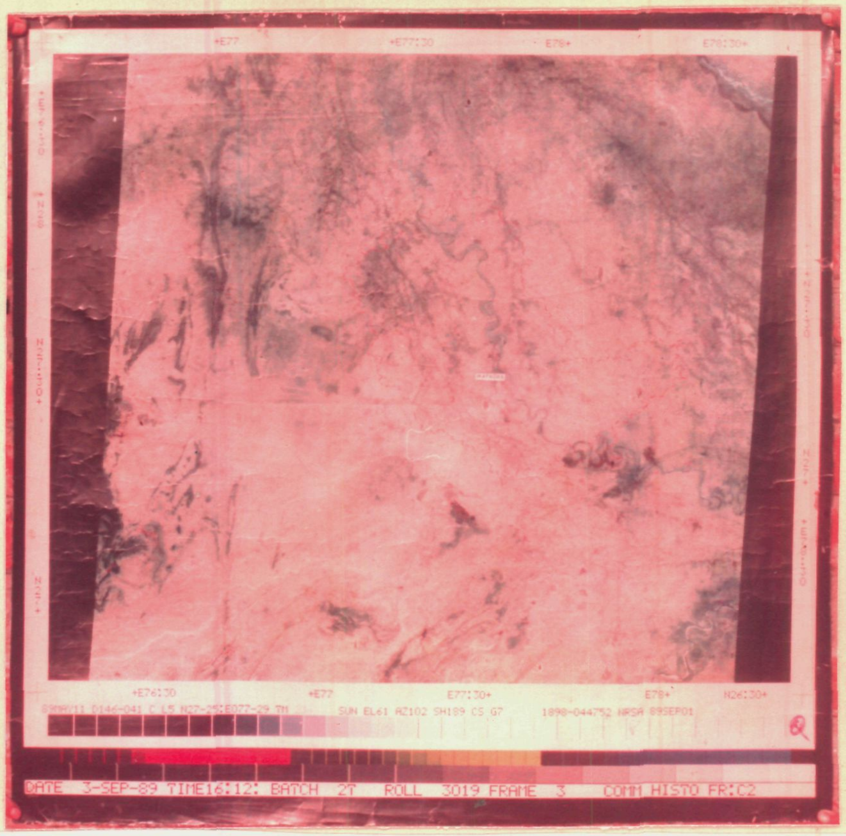


Plate-1 LANDSAT-TM, FCC (B: 2,3 & 4) image of the study area.

3.2 Geographic Setting

The Mathura district is situated in western periphery of the Uttar Pradesh State and north-western part of Agra division. It falls between north latitude 27° 17' - 27° 58' and east longitudes 77° 18' - 78° 12'.

The district is included in the survey of India Toposheet nos. 54E, F & 54E/5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16; 54I/2, & 3.

The district is bordered by the Haryana State in the north, the Rajasthan State in the west, the Aligarh district in the north-east, the Etah district in the east and Agra district in the south (Figure-2).

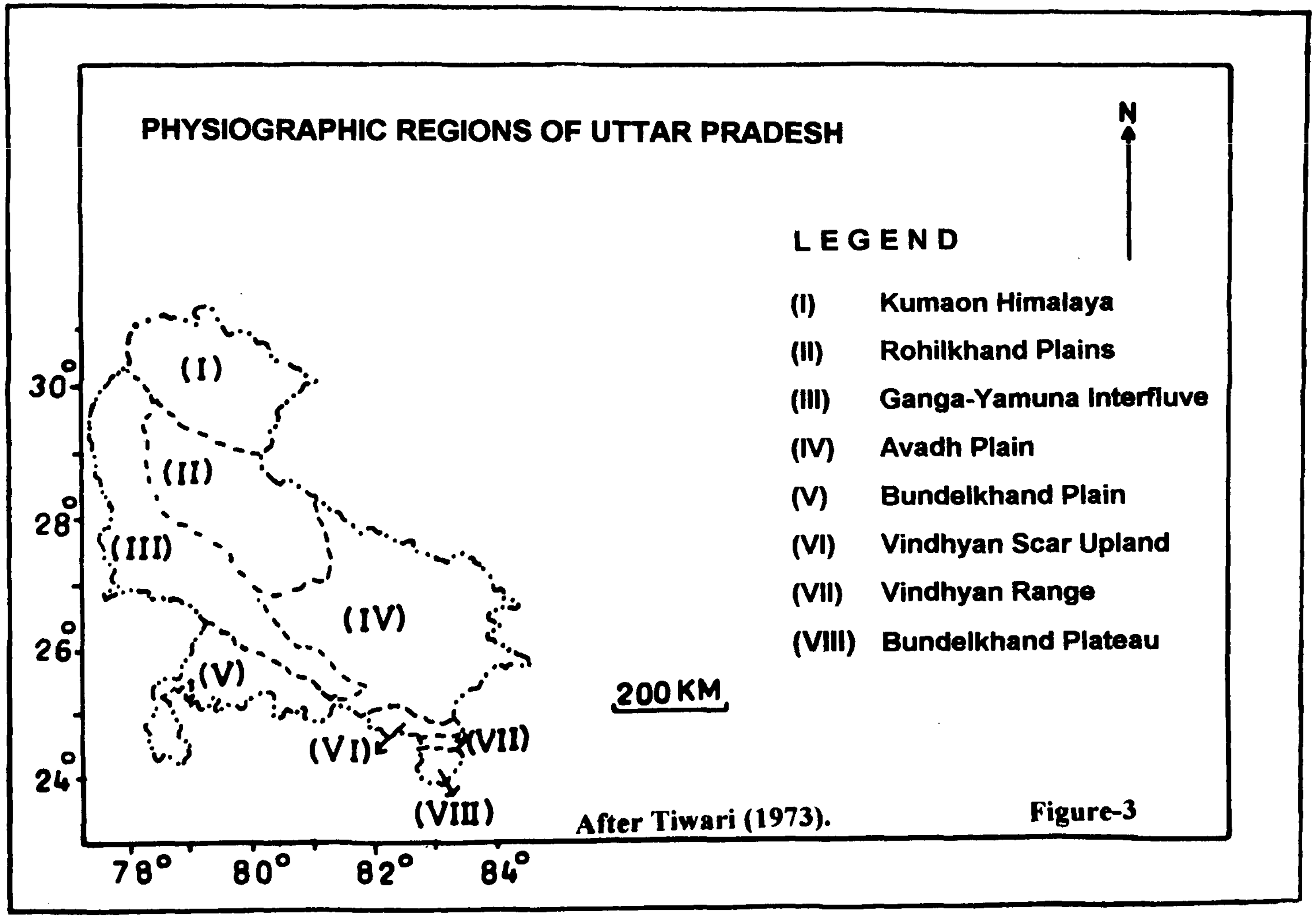
3.3 Physiography and Climate

Physiographically, Uttar Pradesh State is sub-divided into eight broad physiographic regions (Figure-3) viz.,

i) Kumaon Himalya,
ii) Rohilkhand Plains,
iii) Ganga-Yamuna (Doab),
iv) Avadh Plain,
v) Bundelkhand Upland,
vi) Vindhyan Scar Upland,
vii) Vindhyan Range, and
viii) Bundelkhand Plateau.

Mathura District lies in the basin of the Yamuna river and is more or less plain, large area is subjected to fluvial action up to Mahaban and in its onward course river becomes more closely confined between its bluffs, the strips of cultivable land on either side growing more narrow and precarious.

Environmentally, the district lies in the semi-arid ecosystem. The climate of the area is mainly dry intensely hot during summer and quite cold during winter. The minimum temperature generally ranges from 7°C in January to 26°C during May and sometimes falls upto 1°C in the month of January. The maximum temperature during January is about 23°C while in June it is 45°C.



After Tiwari (1973).

Figure-3

In July-August heavy precipitation takes place. The average annual rainfall in the district is 586.9 mm. as recorded from different rain gauge stations from 1982 -to- 1992. The south-western part of the district receives 550 mm. rainfall which gradually increase to 700 mm. in the north-eastern part of the district. The data were statistically analyzed and results have been presented in table-4. The highest rainfall recorded in the district is 828.3 mm. (1983) whereas the lowest rainfall is 409.6 mm. (1986). The standard deviation and the coefficient of variation are 121.40mm. and 34 per cent respectively.

Table-4 Statistical Analysis of Annual Rainfall Data (1982 -to- 1992) of the Study Area (Anon, 1994).

Highest Rainfall (1983)	828.30 mm
Lowest Rainfall (1986)	409.60 mm
Mean	586.90 mm
Standard Deviation	121.40
Coefficient of Deviation	034.00%

3.4 Geomorphology

The process of soil formation in the study area is influenced by geomorphic changes through time. The specific changes in the geomorphology was observed through space borne satellite data, using visual interpretation techniques to delineate geomorphic information for soil resources.

The general slope of the area is from north-west to south-east. The maximum elevation of the alluvial plain is about 178 m. above MSL near the Kotban in Chhata tehsil and the minimum is 171.6 m. above MSL near the Jalesar road, railway station of Sadabad tehsil in the eastern most part of the district. However, residual hills and ridges are scattered at few places in the western most part of the study area (Figure-4).

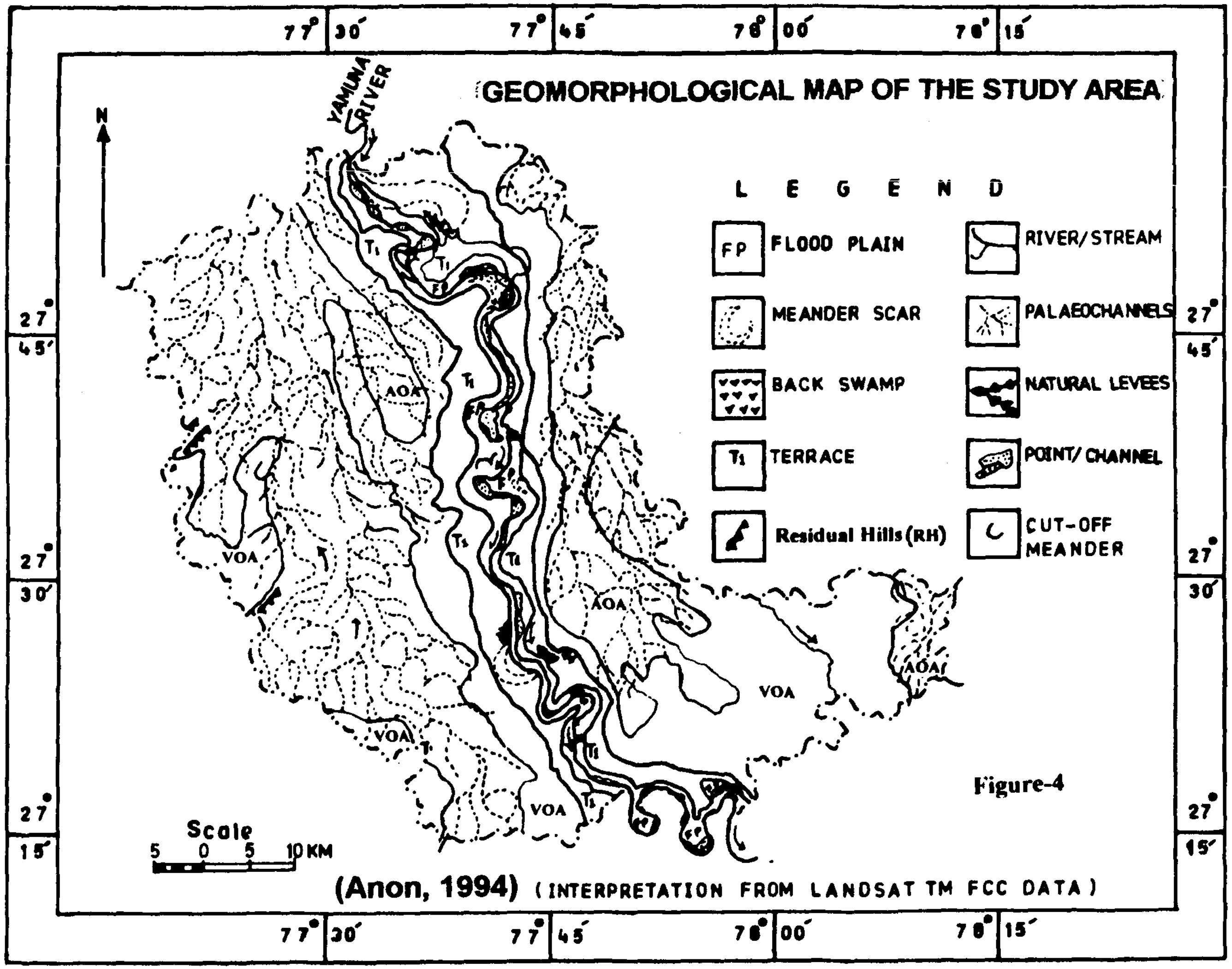


Figure-4

(Anon, 1994) (INTERPRETATION FROM LANDSAT TM FCC DATA)

3.4.1 Geomorphic Zones

Five geomorphic zones have been identified based on photo-elements and geo-technical elements in the study area (Anon., 1994) which are characterized by different geomorphic elements / units, and relief characteristics etc.

1. Varanasi Older Alluvial Plain,
2. Aligarh Older Alluvial plain,
3. Terrace zone (T_1),
4. Recent flood plain of Yamuna river (FP), and
5. Residual hills (Cuesta & Hogback zones).

3.4.2 Drainage

Comparison of palaeo-drainage and present day drainage system for soil resources study was carried out in Mathura district.

The present day drainage network in the study area exhibit by Yamuna river, which flows through the central part of the district, dividing it into two distinct land-masses (Figure-5). In the western part it is observed that there is a complete absence of natural surface drainage, while in the eastern part, two small streams; Jhirna and Patwaha drain the area (Figure-5). The drainage map of the study area is based on SOI toposheets and Landsat-TM (FCC) image.

The Yamuna river represents a meandering river and its course of migration is different in different places, the general shift being from west to the eastern direction (Bakliwal & Sharma, 1980).

Besides, the present day drainage system in the district, the palaeo-drainage network has also been visually interpreted from the TM data. This palaeo-drainage was originated from the Vindhyan upland in the south and drained the Varanasi Older Alluvial Plain into the central depression around the Meerut at Upper Ganga-Yamuna (*Doab*) (Iqbaluddin *et. al.*, 1994).

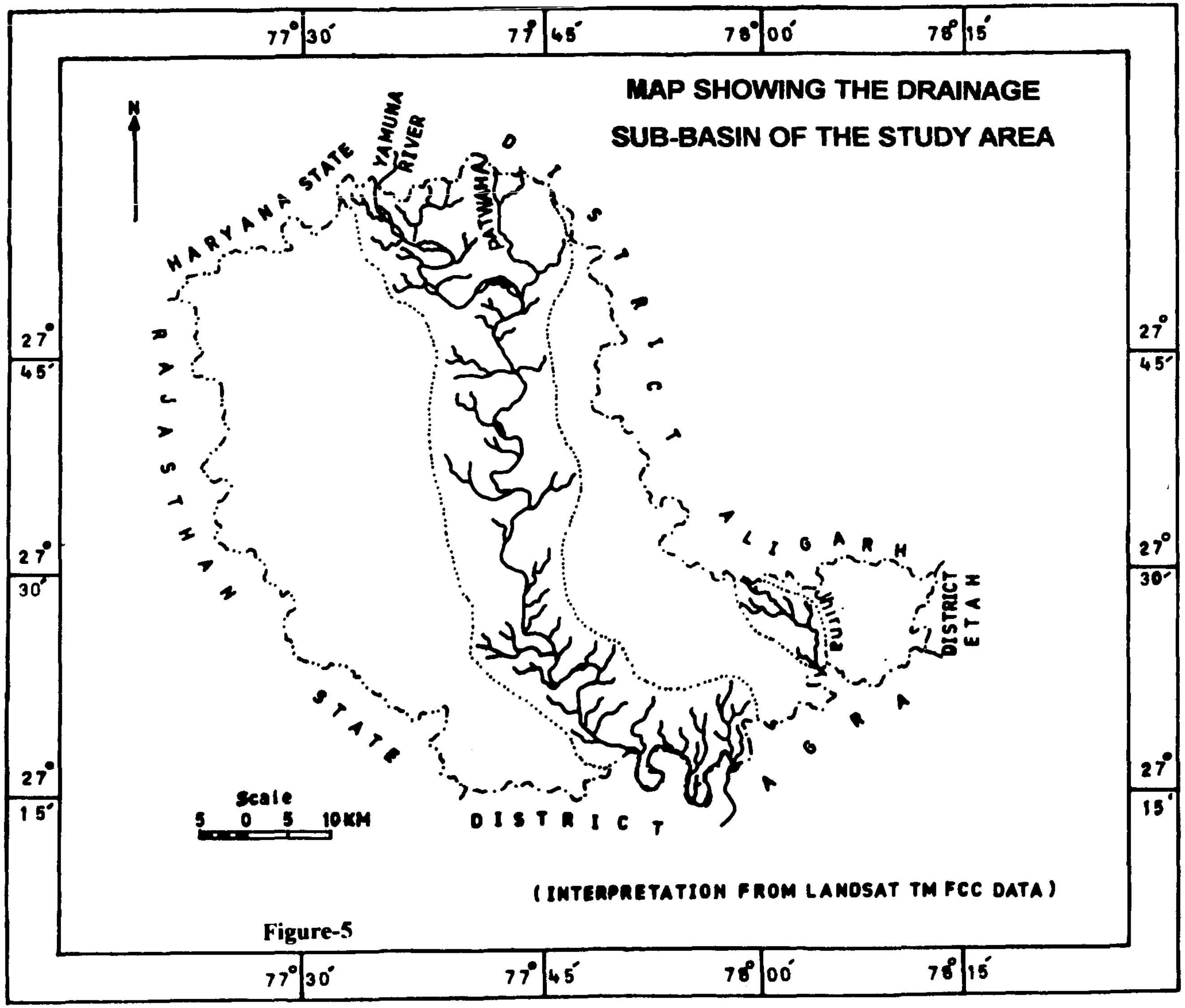

MAP SHOWING THE DRAINAGE
SUB-BASIN OF THE STUDY AREA
N
HARYANA STATE
YAMUNA RIVER
PATWAHA
DISTRICT
ALIGARH
Jhirna
DISTRICT ETAH
AGRA
DISTRICT
RAJASTHAN STATE
Scale
5 0 5 10KM
(INTERPRETATION FROM LANDSAT TM FCC DATA)
77° 30′
77° 45′
78° 00′
78° 15′
27° 45′
27° 30′
27° 15′

Figure-5

The present day drainage has been sub-divided into two sub-basins: Yamuna sub-basin and Jhirna sub-basin (Figure-5), the palaeo-drainage network has also been sub-divided into nine sub-basins: Y_1, Y_2, Y_3, Y_4, Y_5, Y_6, Y_7, Y_8, and Y_9 (Figures: 6 and 7) on the basis of drainage characteristics. The major parts of the palaeo-drainage zones are in the west of the Yamuna river. Hence, this fertile alluvial land has a potential for supply of groundwater to agriculture lands. Figure-7 shows drainage system (Present day and palaeo-drainage, sub-divisions and sub-basins) of Mathura district U.P.

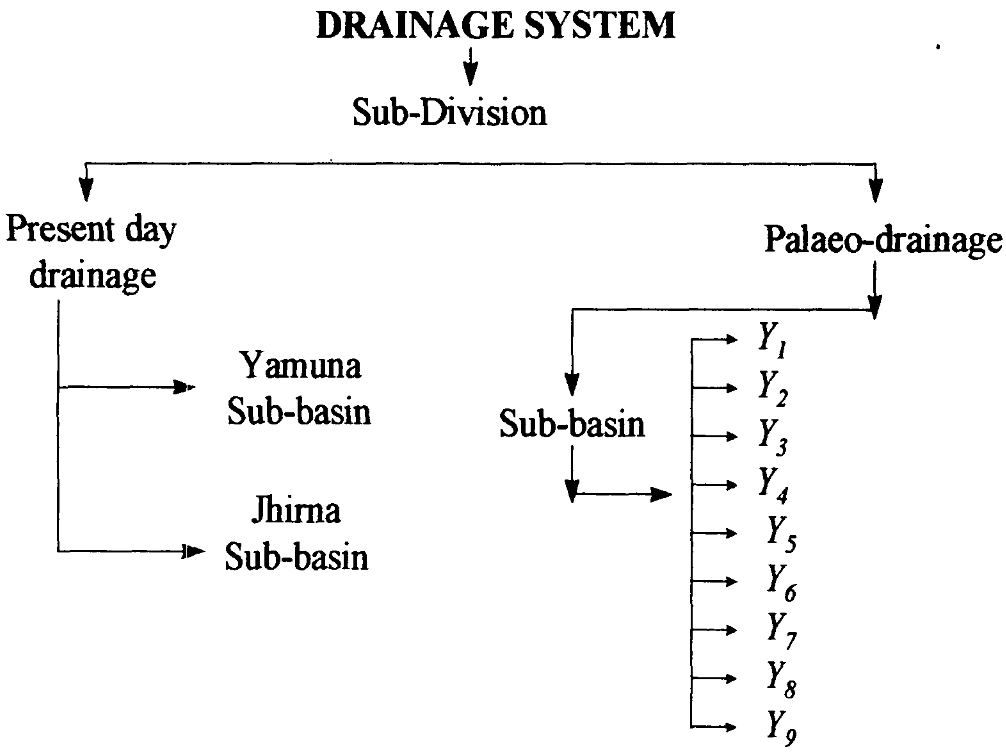
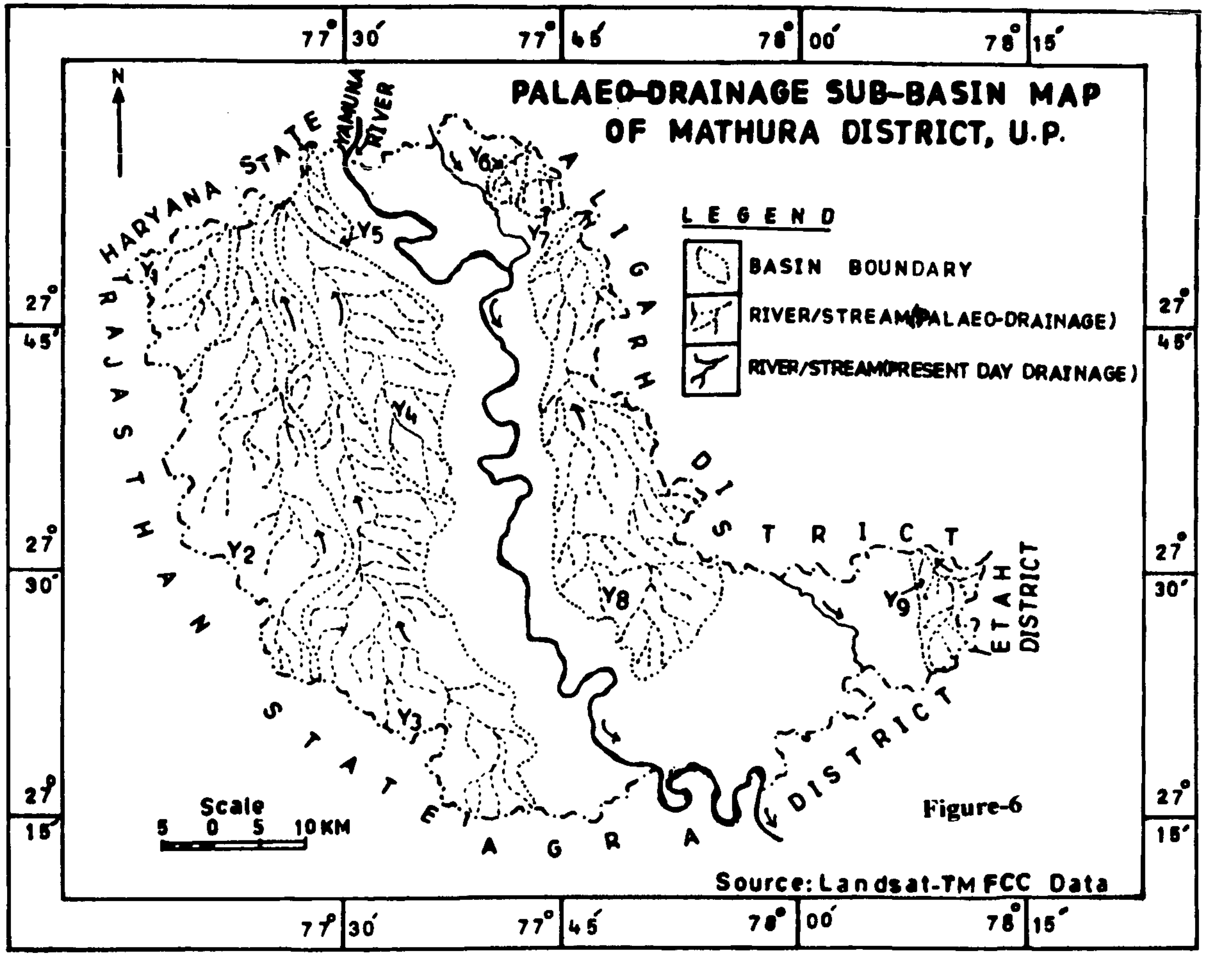


Figure-7


PALAEO-DRAINAGE SUB-BASIN MAP
OF MATHURA DISTRICT, U.P.
LEGEND
BASIN BOUNDARY
RIVER/STREAM(PALAEO-DRAINAGE)
RIVER/STREAM(PRESENT DAY DRAINAGE)
N
YAMUNA RIVER
HARYANA STATE
RAJASTHAN STATE
ALIGARH DISTRICT
ETAH DISTRICT
AGRA DISTRICT
AGRA STATE
Y2
Y3
Y4
Y5
Y6
Y7
Y8
Y9
Scale
5 0 5 10 KM
77° 30'
77° 45'
78° 00'
78° 15'
27° 45'
27° 30'
27° 15'
Figure-6
Source: Landsat-TM FCC Data

3.5 Geology

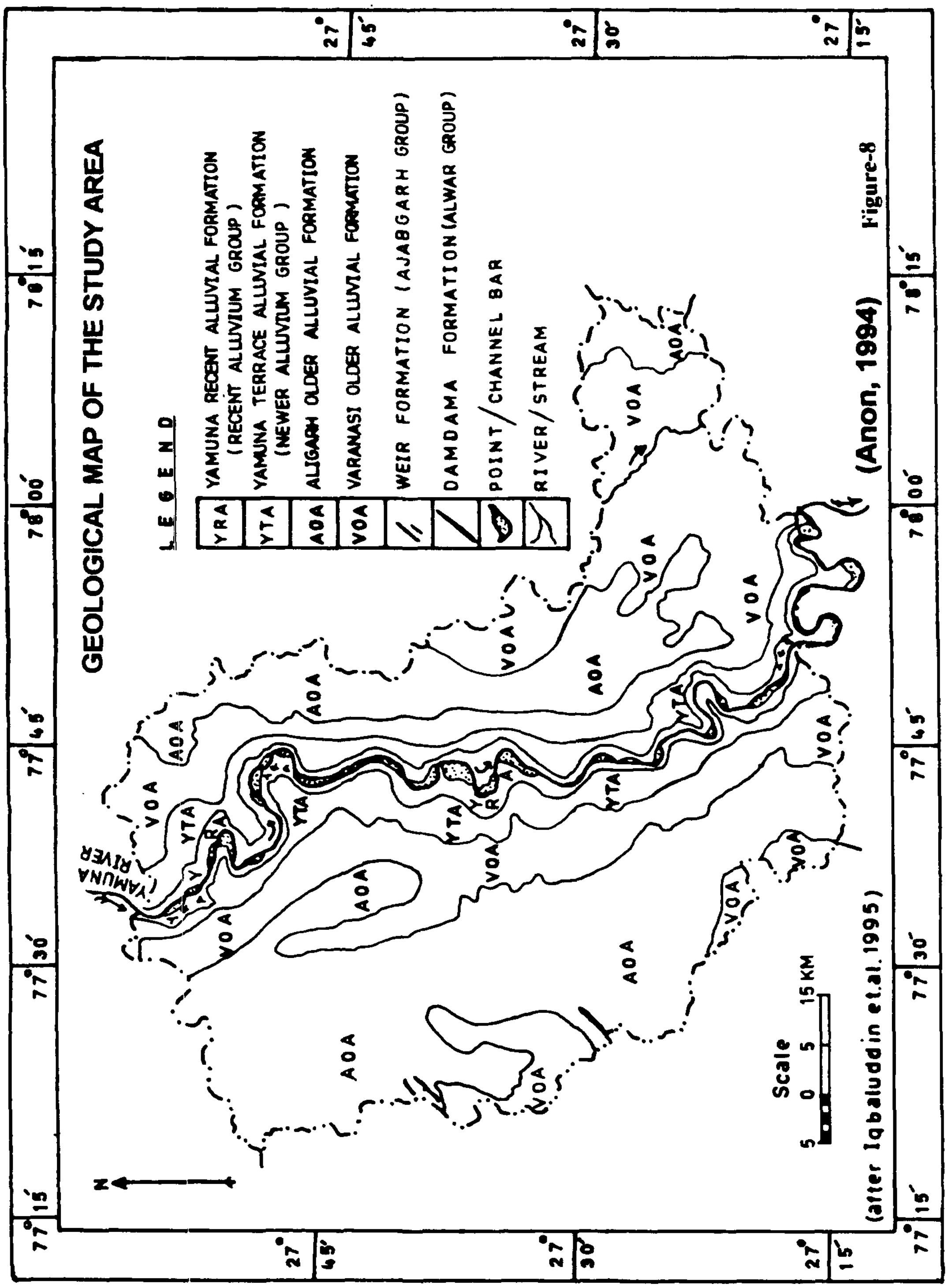
The study area constitutes a part of the plain and is covered with quaternary sediments. The sediments are by and large alluvial in nature comprising silt, sand and clay. However, the pre-cambrian rocks (Delhi super group) are exposed in the westernmost part of the district. The rocks of Delhi super group have been divided into the Alwar and Ajabgarh group (Singh, 1991). Figure-8 shows the geological map of the study area based on visual interpretation of Landsat TM (FCC) data and limited ground-truth (Iqbaluddin, *et. al.*, 1994). The Vidhayan rocks are present as sub-groups in the district and form the basement over which quaternary sediments were laid down in the Indo-Gangetic Plain (Rao, 1973; Shastri, *et. al.*, 1971). The depositing of terrigenous clastic in the negative tectonic topography during the quaternary period is represented by the Older Alluvial group, Newer Alluvial group and Recent Alluvial group. The clastics were supplied by the newly risen mountains of Himalayas in the north and the Vindhyan plateau in the south (Iqbaluddin, *et. al.*, 1994).

3.6 Groundwater

Surface water bodies (Figure-9) and sub-surface water (Figures: 10 & 11) have major effects on the soil resources, both of which vary over time and seasonally.

Groundwater condition for soil resources study is very important because the water saturated condition in the soil alters many physico-chemical characters in the soil profile and root zones as well as surface soil.

The sub-surface study shows that the district has a mixture of fine sand, clay, silt and *kankar* up to a depth of about 70 meters. The aquifer zones occurring within the depth of 50 m.b.g.l. Consisting mainly of fine sand and *kankar*, varying in thickness from 3 to 25 meters have been grouped as shallow aquifer (Anon., 1994). The deeper aquifers are lying in the district below the depth of 50 meters down to the depth of bed rock.



(Anon, 1994)

Figure-8

Table-5 Range of Water-level in Pre-monsoon and Post-monsoon in the four Tehsil of the Study Area (Anon, 1994).

Tehsil Name	Pre-monsoon Min. (m)	Pre-monsoon Max. (m)	Post monsoon Min. (m)	Post monsoon Max. (m)
Mathura	01.30	23.80	00.60	22.80
Sadabad	07.85	25.70	06.90	24.20
Mat	02.90	15.15	02.20	14.85
Chhata	03.35	11.65	03.15	09.80

The thickness of the aquifer ranges between 2 to 50 meters. These aquifers are generally semi-confined to confined in nature (Anon., 1994).

The depths to water level maps were prepared to show the regional variation of water level all over the district. Depth to the water level data in June 1994 and November 1994, were utilized for the preparation of depth to water level maps for pre-monsoon and post-monsoon are shown in Figures: 10 &11 and in table-5.

In the pre-monsoon, the minimum level is 1.30 m.b.g.l. found in village Mustafabad of the Mathura tehsil and maximum water level is 25. 70 m.b.g.l. at Barauli, Sadabad tehsil. The area with the shallow water level is spatially associated with the canal's network.

In the post-monsoon, the water level ranges between 0.60 -to- 24.80 m.b.g.l. in Mathura and Sadabad tehsils respectively. The areas where the water levels are very shallow or near the surface are classified as waterlogged areas. The area along the river Yamuna shows deeper water level and it becomes shallower away from the river. Water level in Sadabad tehsil was deeper as compared to other three tehsils of the district (Table-5).

The annual water level fluctuation map (Figure-12) for pre-monsoon, of the district shows that there is a rise in water level in post-monsoon within a range of 0.1 -to- 3.25 m.b.g.l. presented in figure-12.

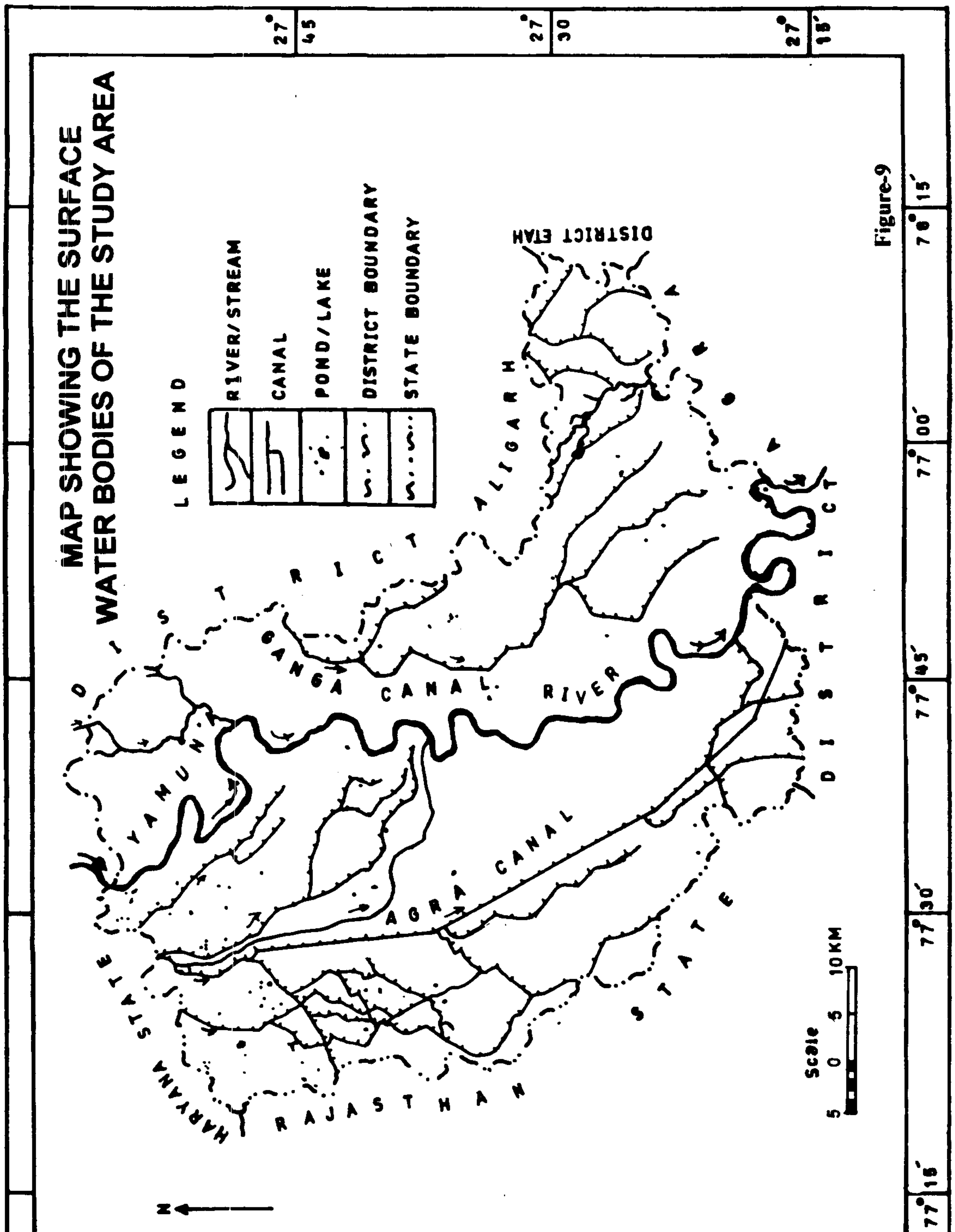

MAP SHOWING THE SURFACE WATER BODIES OF THE STUDY AREA
LEGEND
RIVER/STREAM
CANAL
POND/LAKE
DISTRICT BOUNDARY
STATE BOUNDARY
DISTRICT ALIGARH
YAMUNA
GANGA CANAL
RIVER
AGRA CANAL
HARYANA STATE
RAJASTHAN STATE
DISTRICT
DISTRICT ETAH
Scale
5 0 5 10KM
N
27° 45
27° 30
27° 15'
77° 15'
77° 30'
77° 45'
77° 00'
78° 15'

Figure-9

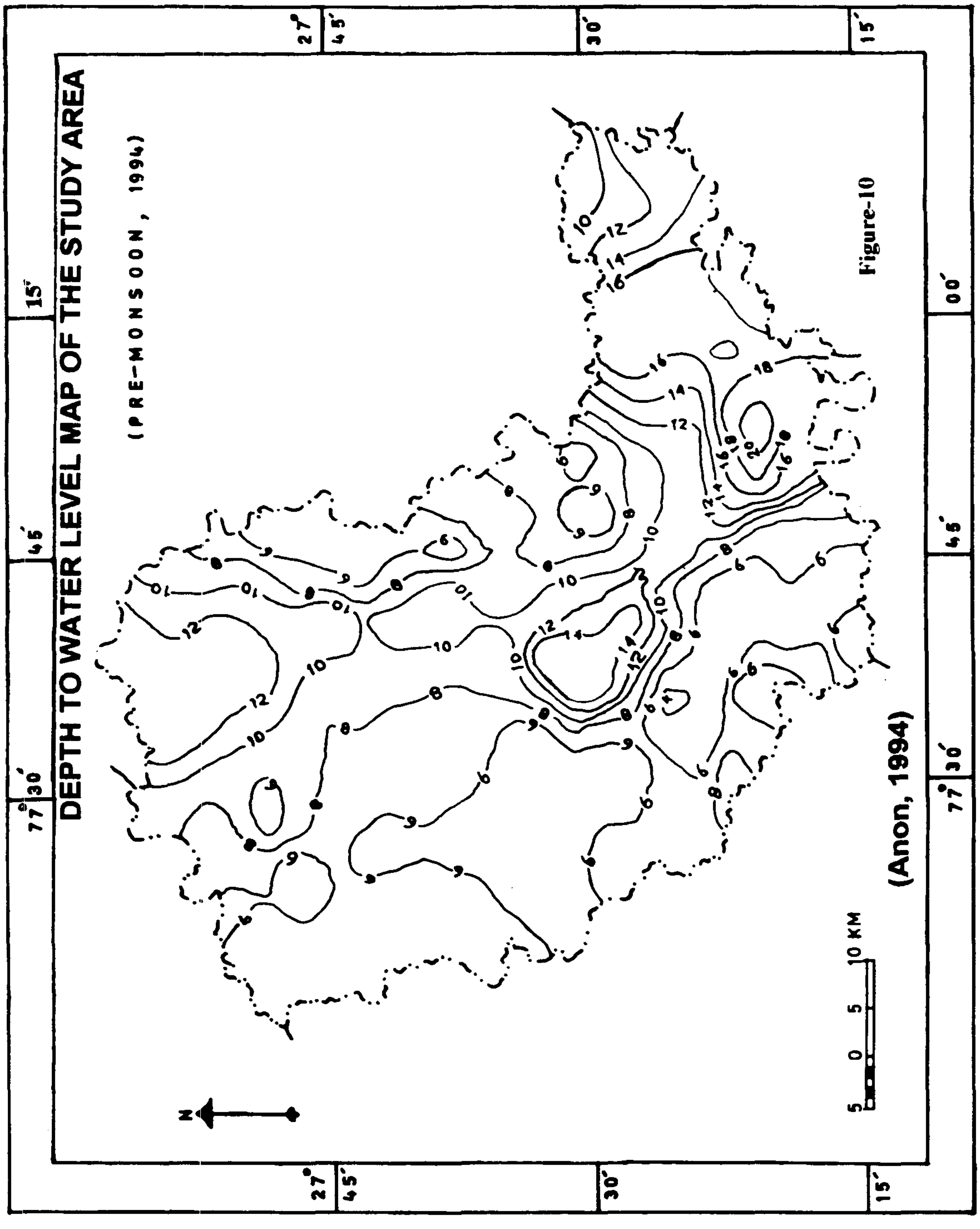


Figure-10

(Anon, 1994)

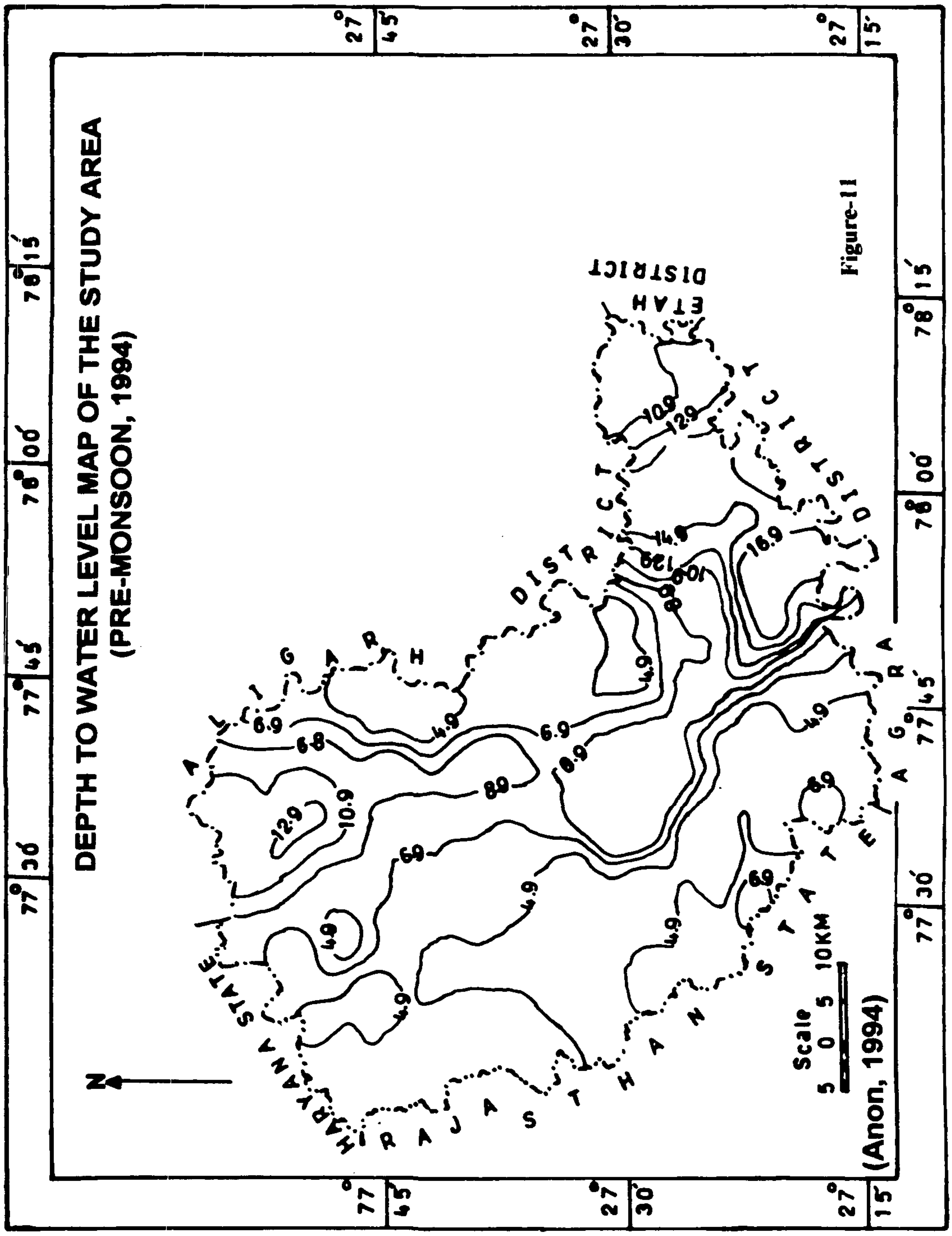
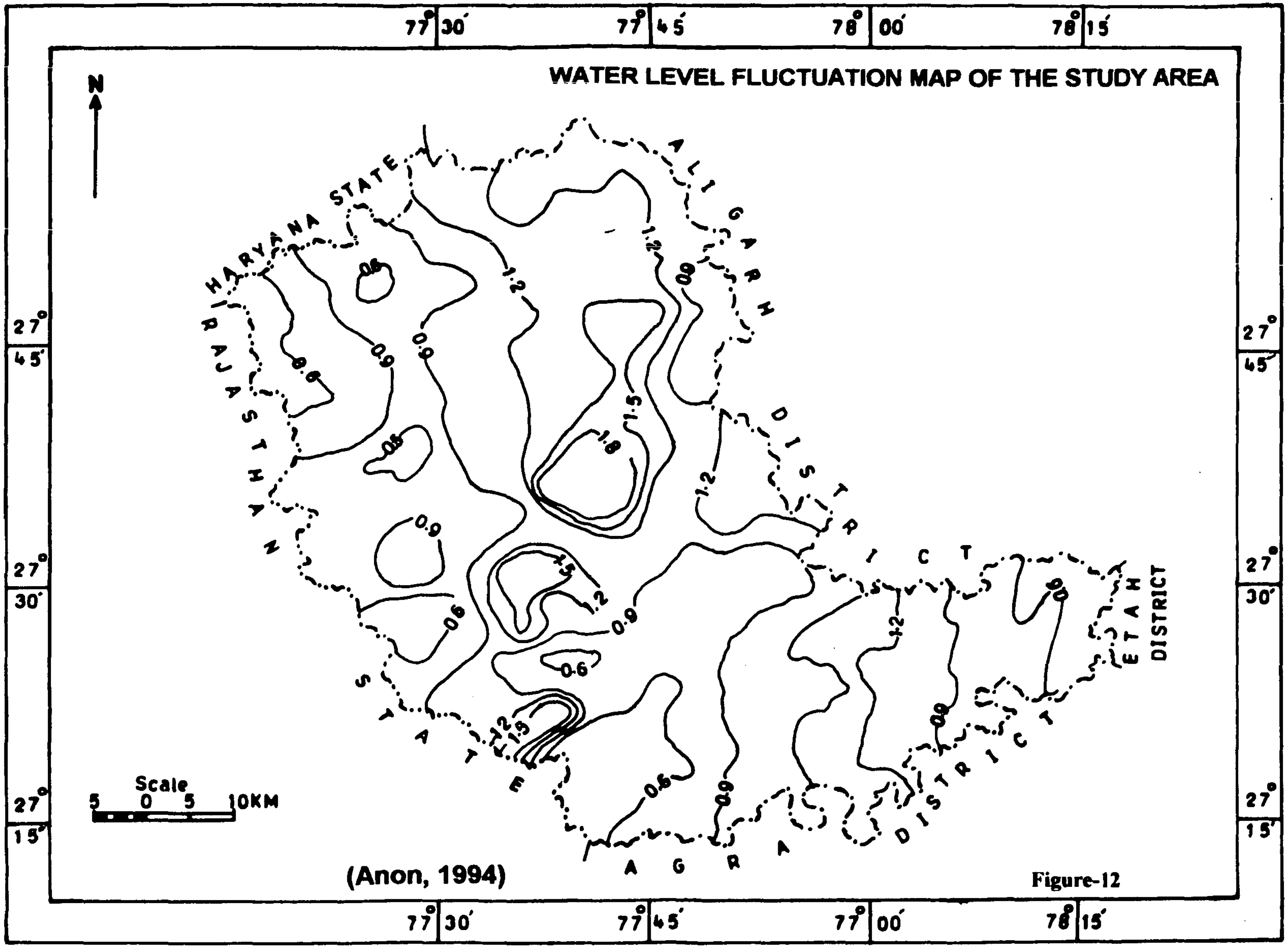

DEPTH TO WATER LEVEL MAP OF THE STUDY AREA
(PRE-MONSOON, 1994)
ALIGARH DISTRICT
ETAH DISTRICT
HARYANA STATE
RAJASTHAN STATE
AGRA DISTRICT
Scale
5 0 5 10KM
N
(Anon, 1994)

Figure-11



(Anon, 1994)

Figure-12

The net annual recharge in the district is 79012.00 ha m., where the net annual drought is 42691.46 ha m. Hence, the unutilized groundwater resource available for development in the district is 36320. 54 ha m. (Anon., 1993-94).

The quality of groundwater in most part of the Mathura district except at some small pockets is reported as saline & brackish in nature. However, fresh water is available in the Yamuna river, Agra canal and also in the area near to the west of Yamuna river below the depth of 50 m.b.g.l. (Anon., 1994).

3.7 Natural Vegetation

The natural vegetation under forest & shrub-land whether reserved, unreserved or protected forest.

The study area is plentiful supplied with trees of the deciduous types and tropical shrub and thorn. The chief trees are: Babool, (Aca*cia nilotica (L.) Del*), Shisham (*Dalbergia sisoo Roxb.*), Neem (*Azadirachta indica A. Juss.*), Pipal (*Ficus Religiosa L.*), Khirni (*Manilkara Hexandra (Roxb.) Dub.*), Siris (*Albizia lebbeck (L.) Benth.*), Jangal Jalebi (*Pithecellobium Dulce (Roxb.) Benth.*), Sirasa (*Alibizia ordoratissnia*) and Khajur (*Phoenix Humilis Royle*), etc.

CHAPTER-IV

METHODOLOGY

METHODOLOGY

In chapter 1 and 3, the location, physiography and climate of the study area have been described along with other features such as geomorphology, geology and the details of natural vegetation, drainage and ground water resources available in the area. The methodology of acquiring various types of data from the study area is the topic of this chapter and the flow chart of the methodology adopted is presented in figure-13.

4.1 Visual Interpretation of Satellite Image for Mapping Soils

The satellite image used for visual interpretation was obtained from Landsat-TM. The resolution of TM sensor is 30m. Detailed specification of the Ladsat sensors is given in Appendix-C. The Landsat-TM data pertaining to path-row: 146-041 covers the study area. False colour composite (FCC) print on 1:250,000 scale of May 11, 1989 for the study area was used in conjunction with SOI toposheets for extraction of information regarding soils. Thematic maps have been also prepared to depict the geomorphology, drainage system and geology from the imagery.

The photo-element and geotechnical elements were used during the visual interpretation of image for the identification of different soil types in conjunction with the published soil reports. Image characteristics such as colour, tone, texture, pattern and association were used following Sabins (1986) and Colwell (1983). This was supported by limited field checks. The Handlens, Dynascan and other supporting material were also used for the delineation of relevant information from the image.

Interpreted details and thematic boundaries were transferred onto the prepared base map. The natural and man-made features were matched with minor adjustments.

FLOW CHART SHOWING THE METHODOLOGY ADOPTED

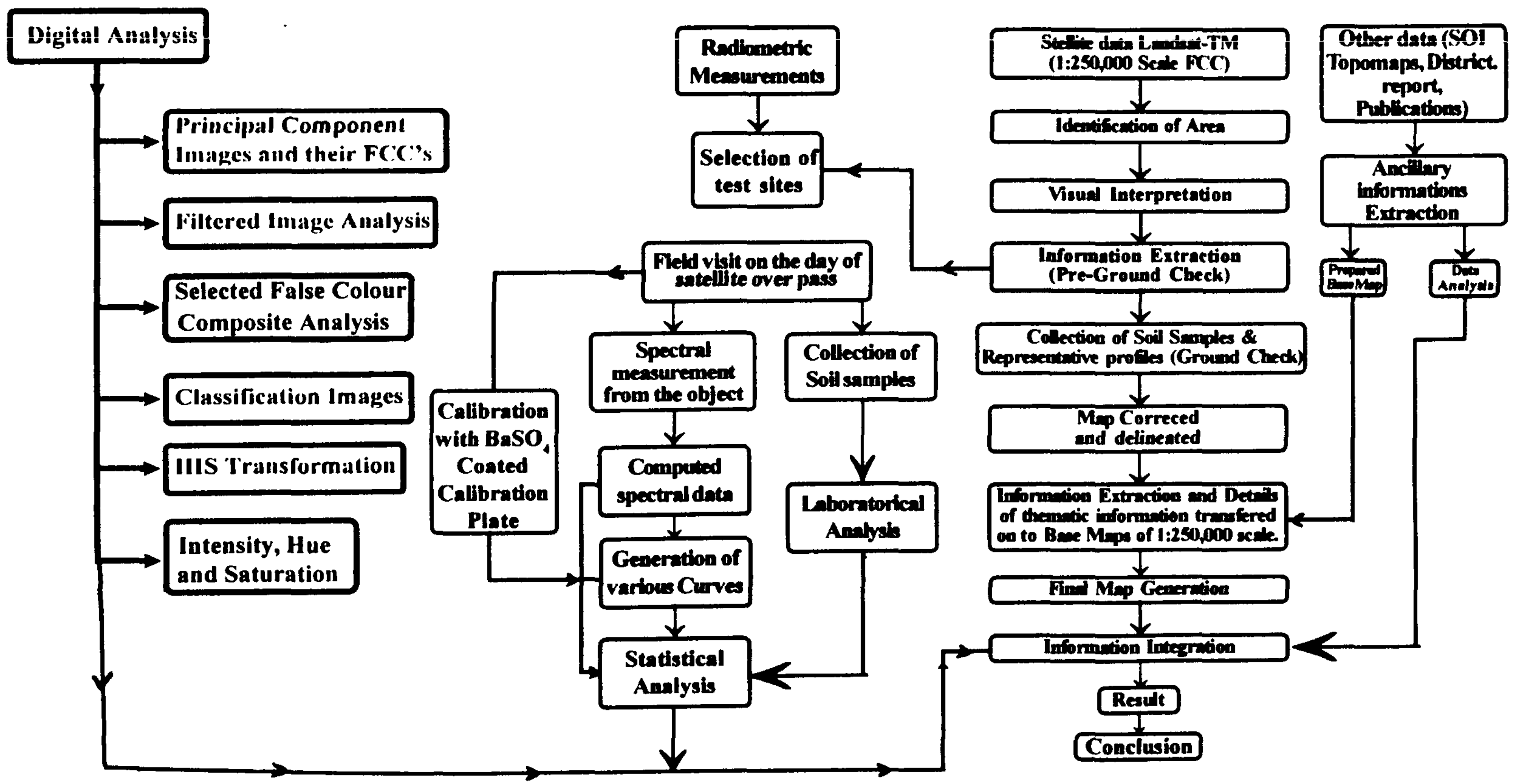


Figure-13

Thus, the physiography-soil units were delineated and preliminary interpreted maps prepared. The sample sites were selected from the delineated units for field checking randomly.

The study area falls in two Survey of India (SOI) sheets Nos. 54E, and F on 1:250,000 scale. Sheets Nos. 54E/5, 54E/6, 54E/7, 54E/9, 54E/10, 54E/11, 54E/12, 54E/13, 54E/14, 54E/15, 54E/16, and 54I/2, 54I/3, on 1:50,000 scale of the above area were also used as a supporting information for delineating the terrain condition.

Base map was prepared from the toposheets on 1:250,000 scale and relevant information were transferred on it after visual interpretation of the satellite imagery.

The soils of the study area were visually interpreted from the remotely sensed data on the bases of photo-elements and geotechnical elements (image characteristics) such as colour, tone texture, association and pattern analyses following Sabins (1986) and Colwell (1983).

4.2 Field Study

The field survey was carried out in the sample site and the soil maps delineated from the image were corrected on field after ground verification.

About 40 samples of surface soil (upto 25 to 30 cm. depth) were collected from various locations on the basis of visual variation of soil characters. Physico-chemical characters for samples have been measured in laboratory.

Soil profiles have been collected from the selected location in the field and soil morhological characteristics of profiles noted.

36 soil samples were collected from the different horizons of the selected profiles

The field observations were noted down in field diary as per the guidelines of Soil Survey Mannual (IARI, 1970).

The morphological observation of soil horizons were done on the basis of variation in colour, mottling, texture, hardness, calcareousness, kankar (*Nodules*), root content, structure and organic matter.

During this phase, additional information regarding drainage, canals, vegetation cover, soil conditions were also noted.

Approximately 1.50 Kg. of soil sample was taken from each site. These samples were stored in polythene sample bags bearing written marks and symbols viz. Location name, horizon nos., and village code and soil colours. The Munsell soil colour charts (1975, edi.) were used in the field as well as in the laboratory for soil colours and Munsell soil colour designations.

The representative soil samples and their brief description of each soil series were described in the field and later on these soil were analyzed in the laboratory for their physico-chemical characteristics.

4.3 Digital Analysis of Satellite Data

For the digital analysis, data from IRS-1A satellite was used. IRS-1A LISS II, frame A2 data in the form of geometrically corrected computer compatible tape (CCT), which were recorded on May 3, 1991 with path-row nos. 28-48, bands 1, 2, 3, and 4 obtained from the National Remote Sensing Agency (NRSA), Hyderabad, India, This four band spectral digital data has a spatial resolution of 36.25 m. The time of satellite overpass is 1020 hours (IST). The digital CCT image data were displayed on colour monitor for area selection. The selected area has been scanned and 512 × 512 size window has been extracted from the CCT on floppy for digital analysis. The conversion and extraction procedure of digital image data has been completed at NIC office, New Delhi.

The data were transferred in floppy in band interleave (BIL) format and converted to Intergraph compatible format using 'MGE'. Image translator software on Dell system of 1.2.

An IBM R6000 system with EASI/PACE software Version 5.3 was also used for digital image processing at IIRS, Dehradun, U. P. The image has been displayed on monitor and digital image has been selected for a generalized maximum information through computer classification output. The cluster output showing nine spectrally separable classes, after selected training sites for each object in supervise classification techniques, while unsupervised classification is automatically classes the objects on the basis of pixel and classes assign to the image.

The digital analysis has done on PC based image processing "MGE" software package at Remote Sensing Application centre for resource Evaluation and Geo-engineering (RSACREG), Aligarh Muslim University, Aligarh.

512×512 pixels dimension equal to 15.29 percent were used for generating the principle component transform and for its subsequent evaluation for monitoring the spatial extent of salt affected and non-salt-affected soil type. The PC image combined with other bands to generate various FCCs for further soil analyses and their effects on images.

4.4 Post field Study

The laboratory work includes the preparation of soil samples for mechanical, physical and chemical analysis. These analysis were carried out by using standard techniques as given in Laboratory Manual for Soil and Water, U.P., sodic land reclamation project, UPRSAC (Anon, 1995).

4.4.1 Preparation of Soil Sample

The polythene bags containing soil samples and bearing written marks, symbols, codes were left open at the suitable place in the laboratory for a few days to allow the moisture contents to evaporate and to get it dry at room temperature. Subsequently, the procedure was as follows.

i) The soil samples were weighted and mildly crushed with a roller and then passed through a 52 mesh to 270 mesh + pan.

ii) The mildly crushed samples were powdered using an agate mortal and extracted pastes were prepared to use in chemical analysis.

iii) Solution 'A' was prepared according to standard methods for determination of silica and alumina.

iv) Solution 'B' was prepared as per the standard methods for determination of major elements.

4.4.2 Grain Size Analysis (Mechanical Analysis)

The particle size analysis was done by Mechanical Shaker and measured on a percentage basis by weight. The analysis of soil fraction i.e. sand was separated from silt and clay, using a nest sieve nos. from 52 mesh to 270 mesh + pan while remaining sieved soil (270 mesh and pan) were used for the clay and silt content separation by sedimentation-pipetting method (Piper, 1950). According to USDA system (Brady, 1984), the sand, silt and clay percentage were used to establish soil textural classes.

4.4.3 Chemical Analysis

The chemical properties of soil samples were analyzed at RSACREG and at the Department of Geology, AMU, Aligarh, U.P. India, for various parameters of soil samples. Statistical analyses of soils have been carried out by using standard statistical formulas.

4.5 In situ Spectral Measurements

For the spectral study of the soil, the reference map of Landsat-TM and IRS 1A LISS-II were used and plan was prepared to visit the selected target site in the field to measure the radiometric spectral characteristics of soils and other associated objects. Target sites were plotted 3 × 3 meters in the field before the measurements were performed by a multi-band Radiometer (Model - 041).

It has facilities of twelve bands of which only four bands corresponding to IRS bands are used, while the other four bands corresponding to Landsat-TM data and rest is reserved for future expansion. A specification of multi-band ground truth radiometer is presented in table-6.

These eight bands operate in the visible and near infrared region. The following steps were taken before the radiometer was used.

a) First the instrument was calibrated for about 5 minutes to 10 minutes.

b) The instrument was suspended over the target of interest and the radiation reflected by the target area was measured.

c) The calibration was done by GTR calibration coated plate $BaSO_4$.

d) The calibration plate was placed on the terrain surface before measuring the spectral signature of soil type and soil cover. The readings of the radiometer were observed at an approximate height of 1.5 meter above the GTR calibration plate. These readings are considered as incoming of the radiation. The next sets of reading were noted without GTR plate to find reflectance values for objects (Plates nos.: 2 -to- 4). The spectral reflectance was computed as given by Dwivedi *et. al.*, (1981).

Table-6

SPECIFICATION OF THE RADIOMETER (Model-041)

1.	Field of view	:	15° + 2
2.	Spectral bands	:	12 spectral bands in the range from μm to 1.1 μm.
3.	Output	:	On 3.5 digit digital panel range meter, measurement are in the Radiometric Unit of W/Cm^2 - Sr -μ .
4.	Dynamic range	:	0.1×10^{-6} to 30×10^{-3} W/Cm^2 - Sr - μ .
5.	Non-linearity over dynamic range.	:	± 1 %
6.	Temperature coefficient	:	0.1 % C at 650 mm.
7.	Initial stabilization	:	5 minutes
8.	Absolute accuracy	:	± 5 %
9.	Power requirements	:	
i)	Optical head	:	± 18 V at + 5 mA under dark condition.
ii)	Display unit	:	9 V at 300 mA Max.
10.	Size		
i)	Optical head.	:	20 cm × 17 cm × 12 cm.
ii)	Display unit.	:	16 cm × 10 cm × 10 cm.
11.	Total weight	:	3.4 Kg.
12.	Environmental condition		
i)	Ambient temperature	:	5° C to 45° C
ii)	Humidity	:	30% to 90 RH at 40° C

CHAPTER-V

VISUAL INTERPRETATION OF SATELLITE DATA FOR SOIL MAPPING

VISUAL INTERPRETATION OF SATELLITE DATA FOR SOIL MAPPING

5.1 General Statement

The methodology of visual interpretation has been discussed in the preceding chapter. This chapter concentrates on visual interpretation of satellite data for soil mapping. Besides, the physical and chemical characteristics of different soil series have been provided. Visual interpretation of Landsat-TM data has been done for mapping and monitoring the changes in soils and the associated geomorphological features.

The soil formation is directly or indirectly controlled by exothermic and endothermic reactions, which continuously change the physical, chemical and biological characteristics of the soils. These changes in the soils are, accomplished through wetting, drying, heating, cooling, evaporation, weathering, erosion (including leaching), and deposition of material. During these processes, the mobile constituents involved in the reactions are: gases, leachates (in solution and suspension) and biological fluids.

The exchange of mobile constituents through these reactions in soil formation, including both complicated reaction and comparatively simple arrangement of matter, effects the soil on account of pedochemical and geochemical weathering.

The influence of the weathering on soil in which high level of exchangeable base such as calcium, potassium, and sodium are contributed towards the reduction in acidity and increase in alkalinity, depends upon various reactions. These reactions take place during the developmental process of salt-affected soil and arable soils (Singh, *et. al.*, 1989).

The arable soils (normal soil) differ from the salt-affected soils (saline/alkaline soil) in respect of two important properties, viz. the soluble salts and the soil reactions.

The soluble salt content in the soil influence the soil behaviour for crop production in several ways, through the changes in the proportion of exchangeable cations, soil reactions, physical properties, osmosis and ion exchange, toxicity effect, plant root zones, and soil microbes (Gupta *et al.*, 1985).

However, the high crop productivity in salt affected soil can be attained, if the nature of physico-chemical characteristics, and the extent of reactions affecting the salinity problems, are correctly or timely diagnosed and appropriate reclamation and management practices are adopted under favourable environmental conditions. The quick and precise diagnosis of soil in fields of agricultural land is possible by using the satellite images.

5.2 Visual Interpretation of Satellite Image

The soil patterns of the study area were visually interpreted from the remotely sensed data (Figures: 14 and 15) on the basis of the following image characteristics: colour, tone, texture, association and pattern.

The remotely sensed data, pertaining to Landsat-TM false colour composite (FCC), bands 2, 3, and 4 were utilized for soil mapping in conjunction with the SOI topographic sheets and fieldwork in the selected sites. Mapping of soils, directly from remotely sensed data, has been confounded by the complexities of environmental factors contributing to the spectral signals measured by a sensor (De Jong, 1994). Soil types have been delineated by visual examination of Landsat colour composites as well as individual bands (Lewis, *et. al.*, 1975; Westin and Frazee, 1976).

The representative soil profiles from each soil series were studied and described in the field and later soil samples were analyzed in the laboratory for their physico-chemical characteristics.

5.3 Soils of the Mathura District

On the basis of visual interpretation, physico-chemical characteristics, geology, geomorphology, physiography and reflectance characteristics, the soil of the study area has been grouped into the following eight soil series.

5.3.1 Kupa Soil Series (KK),

5.3.2 Mahaban Bangar Soil Series (TYK),

5.3.3 Mathura Khadar Soil Series (YK),

5.3.4 Parkhan (*UsarLand*) Soil Series (UL),

5.3.5 Tarauli Janubi Soil Series (WLL),

5.3.6 Pura Soil Series (WUL),

5.3.7 Kolahar Soil Series (ELL) and

5.3.8 Koyal Soil Series (EUL).

The soil map prepared is presented as figure-14. The extended map legend is given in table-7.

5.3.1 Kupa Soil Series (KK)

This series has been identified on the image by its light lone, smooth texture, regular to irregular pattern and association with Karban river. It occurs in a very narrow belt along the recent flood plain of Karban river in Sadabad tehsil (Figure-14). The soil of this series is young and horizons are undeveloped. It covers about 0.244 per cent (928.97 hectares) of the study area. The profile was studied near Kupa village of Sadabad tehsil and various horizons of this series were recorded (Profile No. II; Appendix-A).

Table-7 SOIL MAP EXTENDED LEGEND

Map Unit	Soil Series	Physiography and Slope	Soil Characteristics	Chemical Characteristics (Surface)		
				pH	EC dSm^{-1}	ESP
YK	Mathura Khadar	Yamuna Recent Plain, Gently to moderately sloping (3-10%)	Light grey, loamy sand in surface, fine sand in sub-surface	8.58	0.17	>15
TYK	Mahaban Bangar	Terrace Zone of Yamuna, Gently to moderately sloping (3-10%)	Light yellowish brown, sandy loam in surface, loamy sand in sub-surface	8.17	0.28	<15
EUL	Koyal	Varanasi Older Alluvial Plain, Very gentle to gently sloping (1-5%)	Yellowish brown, fine sandy in surface, loam to silty loam in sub-surface	8.13	0.23	<15
WUL	Pura	Varanasi Older Alluvial Plain, Very gentle to gently sloping (1-5%)	Light brown, sandy loam in surface, loam to loamy sand in sub-surface	7.64	0.26	<15
ELL	Kolahar	Aligarh Older Alluvial Plain, Nearly level to gently sloping (<3%)	Light greyish brown, loam in surface, silty clay loam in sub-surface	8.23	0.58	<15
WLL	Tarauli Janubi	Aligarh Older Alluvial Plain, Nearly level to gently sloping (<3%)	Greyish brown, sandy loam in surface, silty clay loam in sub-surface	7.91	0.54	<15
UL	Parkhan	Aligarh Older Alluvial Plain, Nearly level (<1%) salt-affected	Light Olive brown, silty clay loam in surface, clay loam in sub-surface	8.65	9.86	>15
KK	Kupa	Recent Flood Plain of Karban river, Gently to moderately sloping (3-10%)	Light brown, loamy sand in surface, silty loam to fine sandy in sub-surface	8.15	0.18	<15

Plate-2 Salt-affected soil (Moist), (Field Photograph).

5.3.2 Mahaban Bangar Soil Series (TYK)

This series is identified by their spectral response patterns and texture on image through visual interpretation. This series is almost parallel to the YK soil series in the form of narrow strip, along east-west banks of the Yamuna river (Figure-14). This series covers about 14.645 per cent (55600.60 hectare) of the study area. The soil of TYK series is mature and occurs on gentle to moderate slope. The TYK soil has been mapped as *Mainther* soil series by the Department of Agriculture (Anon, 1986).

A representative soil profile was examined and the main characteristics of various horizons recorded in profile No. III; Appendix-A), and in figure-23 (f).

5.3.3 Mathura Khadar Soil Series (YK)

This soil series is depicted on image by light tone due to light soil colour, smooth texture, and zig-zag pattern and association with Yamuna river. The YK soil series occurs in the narrow belt along Recent flood plain of Yamuna river in the study area (Figure-14). The YK soil series covers about 4.691 per cent (17811.7 hectare) of the study area. This series is undeveloped, young and strongly alkaline. This series is also known as mixed alluvium soil (Anon, 1986).

A representative soil profile of the series was studied and characteristics of various horizons recorded in profile No.- 1, Appendix-A) and in profile-24(e).

5.3.4 Parkhan Soil Series (UL)

On the image, this series exhibited bright to very bright tone. The tonal differences are on account of differences in salt-concentration and their spectral response variation. The smoothness in texture, irregular pattern, sharp contact and their association with canals and lower physiographic

Plate-3 Salt-affected patches surrounded by dry grass cover over soil (Field Photograph).

situations are clearly seen. This soil series covers about 5.715 per cent (21700.70 hectares) land in the study area.

To delineate the degree of salinity-sodicity (Figures: 14 and 15) in the study area, spectral reflectance of these soils have been measured and presented elsewhere (Chapter-7).

The UL soil series occurs in irregular scattered patches on the ground and are characterized by poor drainage, waterlogging and presence of scattered calcium carbonate concretion (*Kankars*) in the illuvial zone. The lateral movement and infiltration of canal water, stationary water bodies in low-lying areas, within the saturated zone trends to predominate and the extensive spread of salt-affected soils has been formed. This UL soil series is equivalent to *Umarya* soil series mapped by the Department of Agriculture (Anon, 1986).

This series is categorized into two sub-classes: S_1 (saline) and S_2 (sodic) on the basis of physico-chemical characteristics, which can be seen in figure-15.

S_2 soil series is developed in the extreme eastern part of the study area and is less in spatial spread while S_1 soil category is scattered mostly along the major canals in the form of irregular patches.

The boundaries of salt-affected soils are clearly visible on the remotely sensed images. This variation is picked up easily in the field also.

A representative soil profile from UL soil series was studied and characteristics of various horizons recorded in profile-IV; Appendix-A and figure-23(a).

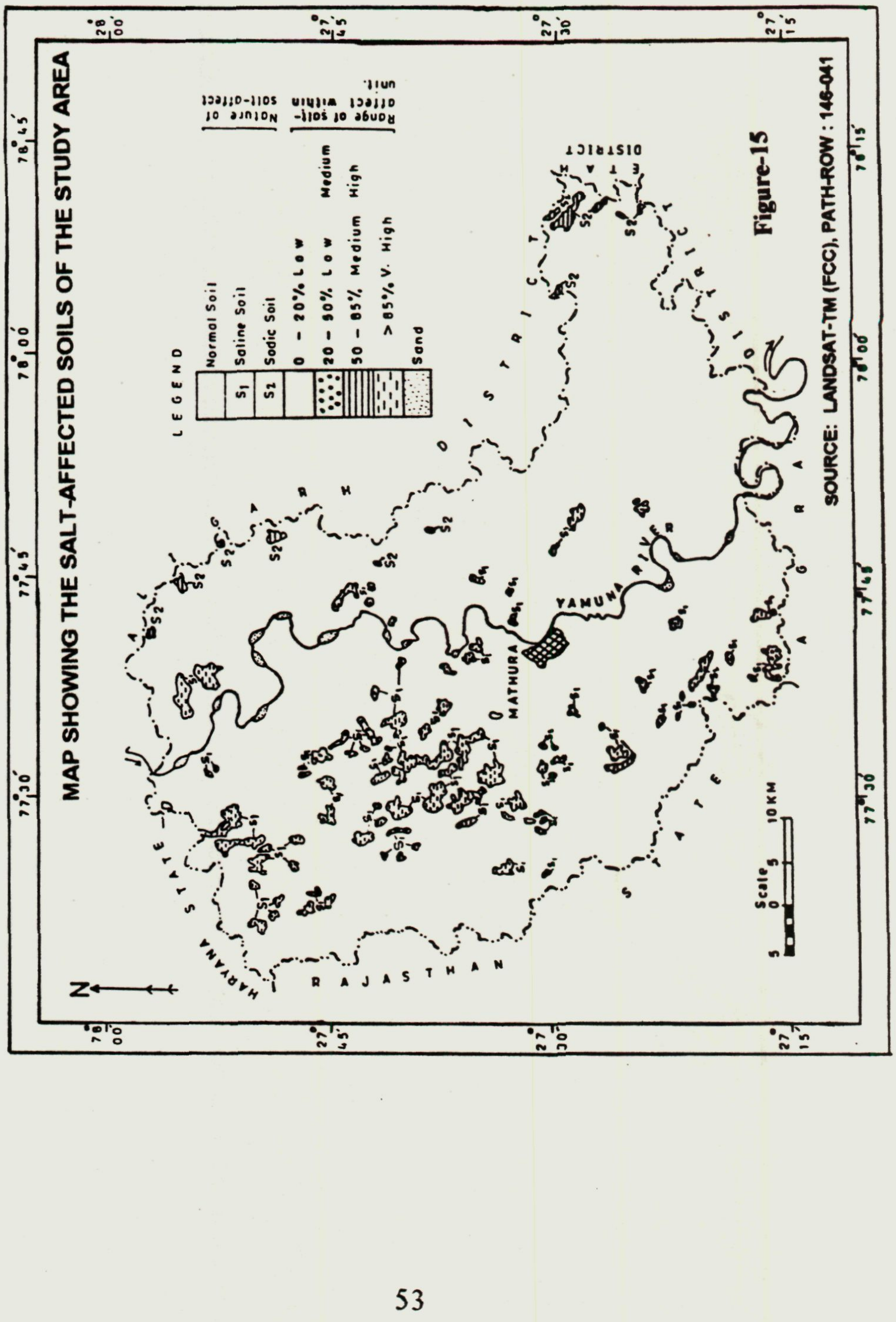

MAP SHOWING THE SALT-AFFECTED SOILS OF THE STUDY AREA
LEGEND
Normal Soil
S_1 Saline Soil
S_2 Sodic Soil
Nature of soil-affect
0 – 20% Low
20 – 50% Low Medium
50 – 85% Medium High
> 85% V. High
Range of soil-affect within unit.
Sand
HARYANA STATE
RAJASTHAN STATE
AGRA DISTRICT
ALIGARH DISTRICT
ETAH DISTRICT
MATHURA
YAMUNA RIVER
Scale 5 0 5 10 KM
77°30′
77°45′
78°00′
78°15′
78°45′
28°00′
27°45′
27°30′
27°15′
SOURCE: LANDSAT-TM (FCC), PATH-ROW : 146-041
Figure-15

Plate-4 Salt-affected soils (dry) with salt tolerant grass cover (Field Photograph).

5.3.5 Tarauli Janubi Soil Series (WLL)

This soil series is explicited by their medium to gray tone where the tonal, patterns vary according to geomorphic positions, texture is smooth as well as coarse. The soil of this series covers about 24.678 per cent (93688.71 hectare) of the area (Figure-14). The WLL soil series is senile, very deep and well drained. It contains scattered small calcium carbonate concretion (*Kankar*) in elluvial zone.

The WLL soil series is also known as *Pinha*, *Kaira*, *Ajnaukh*, *Sigrauri*, and *Tumala*, soil series (Anon, 1986).

A representative profile of WLL soil series was examined and characteristics of various horizons recorded in profile-V; Appendix-A and in figure-23(b).

5.3.6 Pura Soil Series (WUL)

This soil series is identified by its geomorphic position and association with vegetation cover. On the image, this series is depicted by medium to gray tone, medium to coarse texture. This soil series covers about 15.001 per cent (56950.45 hectare) of the study area (Figure-14). The soil of WUL series is senile and very deep.

The drainage is well developed in this series with conspicuous leaching. Topographically, the WUL has very gentle to gentle slope. This series is also termed as *Chaumuha*, *Chhata*, *Bukhari*, and *Dhanauta* soils by Department of Agriculture (Anon., 1986).

A representative soil profile of WUL series was studied and characteristics of various horizons recorded in profile-VI; Appendix-A and in figure-23(c).

5.3.7 Kolahar Soil Series (ELL)

This series is interpreted as medium to gray tone and moderate to coarse texture. Colour patterns vary according to geomorphic features and site characteristics. The ELL soil series covers about 11.823 per cent

(44869.80 hectare) of the study area (Figure-14) Topographically, the ELL occurs on nearly plain to very gentle slopes (<3 per cent). The soil of ELL is senile, deep and well drained with some scattered calcium carbonate concretions (*Kankar*) in the sub-soil. This series is also termed as *Nehra* soil by Department of Agriculture (Anon, 1986).

A representative soil profile of this series was examined and characteristics of various horizons recorded in profile-VIII; Appendix-A and depicted in figure-24(h).

5.3.8 Koyal Soil Series (EUL)

This series is identified by its medium hue and medium to coarse texture. These elements vary according to their site characteristics and geomorphic position. The EUL soil series covers 23.202 per cent (88086.54 hectare) of the study area (Figure-14). It is senile, very deep and well drained.

Topographically, The soil has very gentle to gentle (1-5 per cent) slope. This soil series is also known as *Bhikampur*, *Khandela*, *Bhadrsban*, *Mat* and *Unchagaon*, soils by Department of agriculture (Anon, 1986).

A representative profile of EUL soil series was studied and characteristics for various horizons have been recorded in profile-VII; Appendix-A and is shown in figure-24(g).

5.4 Physico-chemical Characteristics of Surface Soil Samples

This section of the chapter describes the variation of physico-chemical properties of soil series viz. colour range, Texture (sand, silt and clay percentage), structure, moisture content. Further it also deals with geo-technical elements (liquid limit range, flow index range and plastic limit range percentage) which are presented in table-E-1 (Appendix-E). Some of fluctuations in physical parameters are shown in figures-16 and 17 while the chemical properties can be seen in tables E-3 and E-4 (Appendix-E) and in figures-18 and 19.

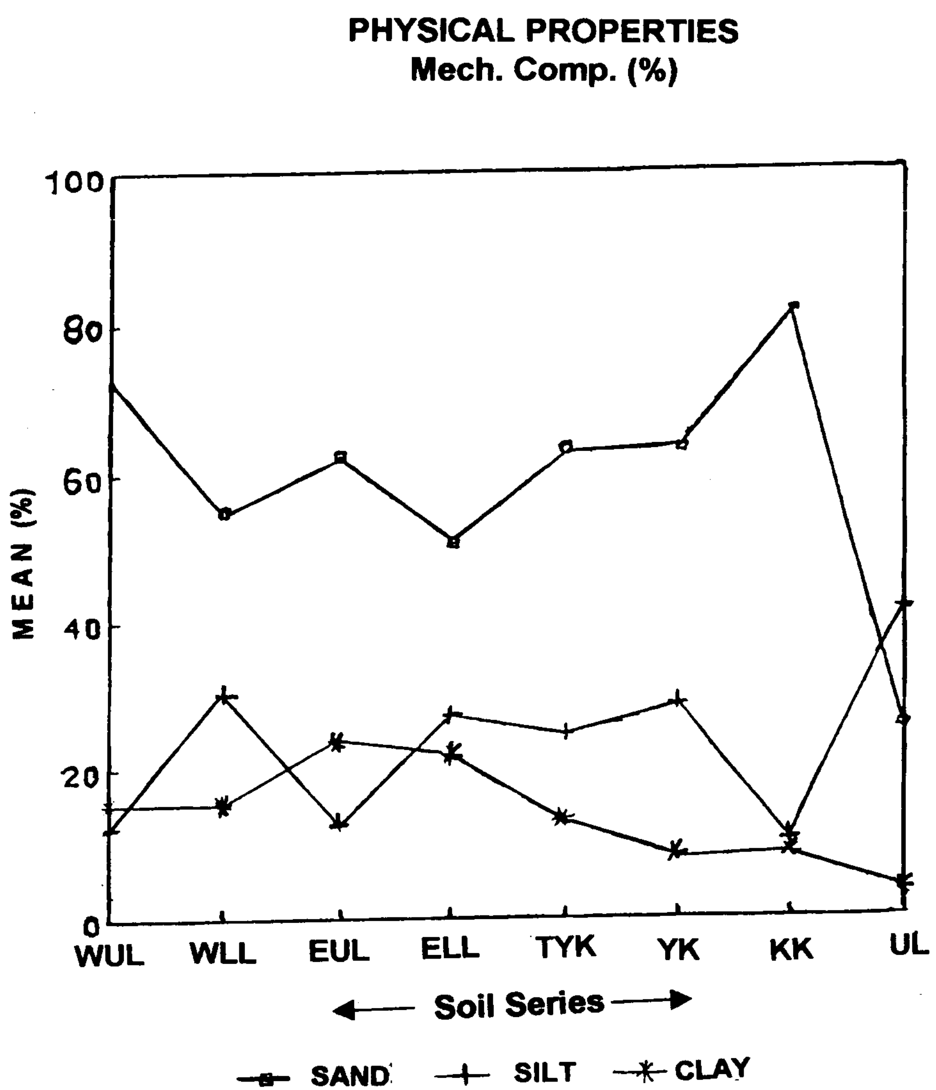


Figure-16

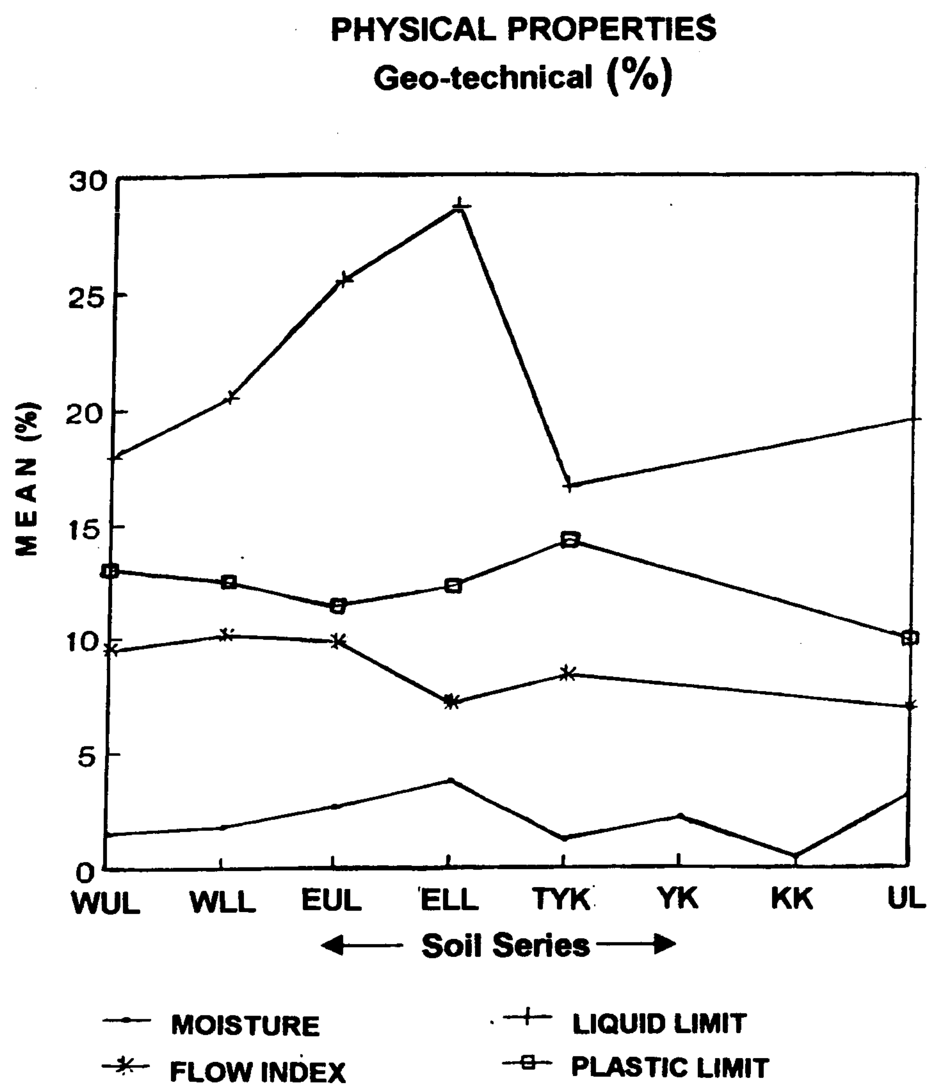


Figure-17

The chemical properties in terms of Cation Exchange Capacity (CEC), Exchangeable Sodium Percentage (ESP), Hydrogen Ion Concentration (pH), Electric Conductivity (EC), and percentage of silica (SiO_2), Alumina (Al_2O_3), Sodium Bicarbonate ($NaHCO_3$), Phosphorous Oxide (P_2O_5), Potassium Oxide (K_2O), Calcium Oxide (CaO), Iron Oxide (Fe_2O_3), Magnesium Oxide (MgO) can be seen in tables: E-3 and E-4 and in figures-18 and 19.

The fertility status of the soil series in term of macro-nutrient percentage: Nitrogen (N), Phosphorous (P) and Potassium (K) are presented in tables: D-3 and D-4 (Appendix-D) and the range of Nutrient Index of soil series for NPK are given in table: D-3 (Appendix-D).

Some of the salient characters of the above mentioned parameters are discussed in the following paragraphs.

5.4.1 Granulometrical and Geo-technical Analysis

The particle size distribution and geo-technical properties of soil series varies from one soil series to another soil series in the epipedon (Figures: 16 and 17), as identified by spectral variation on image whereas YK, KK and TYK have high spectral reflectance on account of coarse textured soil and very less organic matter.

These variations in soil series are observed in surface soil through the texture and their variations based on particle size analysis. Commonly found textures during analysis are: loam, sandy-loam, silty-clay-loam, sandy-clay-loam and loamy sand.

In this section, some of the minor and major fluctuations of physical characteristics of the following soil series are described to differentiate the soil characteristics.

5.4.1.1 KK Soil Series

This soil series has loamy-sand texture and it comprises sand: 81.25%, silt: 10.05% and clay: 8.70% respectively.

CHEMICAL PROPERTIES

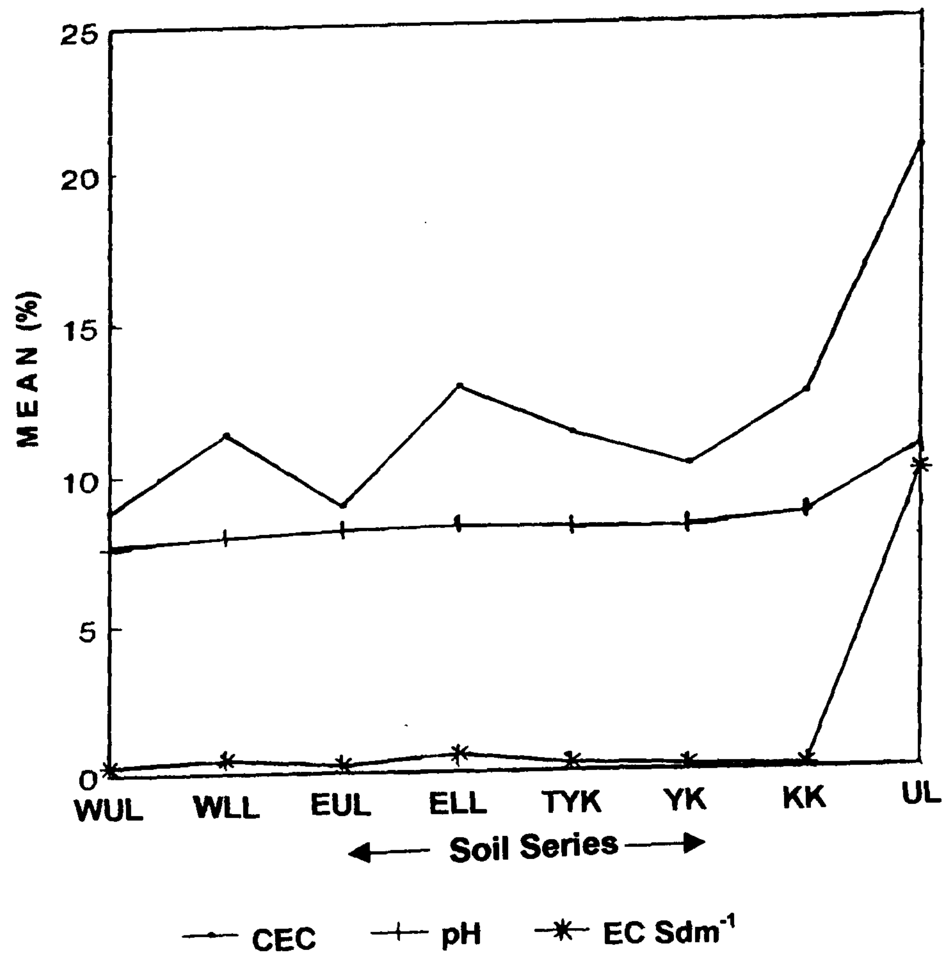


Figure-18

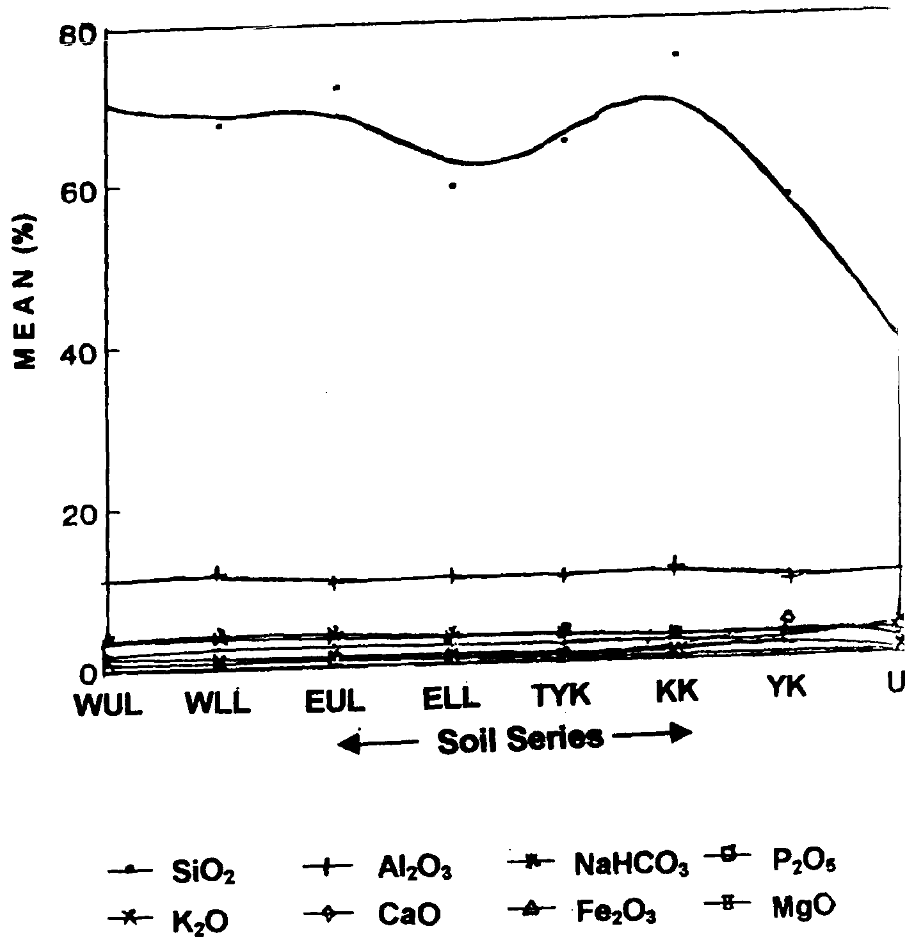


Figure-19

5.4.1.2 TYK Soil Series

Texturally, this soil series is sandy-loam in nature and proportion of sand ranges between 57.87%-66.76%, silt ranges between 17.19%-30.90% and clay ranges between 11.23%-16.05%. The liquid limit ranges between 15.50%-17.75%, flow index ranges between 8.00%-8.50% and plastic limit ranges between 13.43%-15.94%. (Table: E-1; Appendix-E).

5.4.1.3 YK Soil Series

This series represent sandy-clay texture and it comprises sand ranges from 42.16% to 85.00%, silt ranges from 4.18% and clay ranges from 5.50% to 10.82%. (Table: E-1; Appendix-E).

5.4.1.4 UL Soil Series

The texture in this soil series varies from silty loam to clayey loam in it. Sand ranges from 19.59% to 30.50%, silt ranges from 32.30% to 50.31% and clay ranges from 30.11% to 37.20%. The liquid limit ranges from 18.50% to 20.50%, flow index ranges from 4.25% to 9.50% and plastic limit ranges from 8.39% to 11.26%. (Table: E-1; Appendix-E).

5.4.1.5 WLL Soil Series

Textural variation in this soil series is from sandy loam to clay-loam in nature and it comprises sand ranging between 50.87%-59.10%, silt ranging between 16.45%-38.63% and clay ranging between 10.50%-26.82%. This series comprises liquid limit ranging between 16.00% to 28.50% flow index ranging between 5.50%-18.00% and plastic limit ranging between 10.62%-15.49%, (Table: E-1; Appendix-E).

5.4.1.6 WUL Soil Series

This soil series has sandy loam to loamy-sand variation in texture and it comprises sandy ranging from 21.27% to 66.73%, silt ranging from 7.21% to 23.72% and clay ranging 8.36% to 21.27%; this series has liquid limit ranging from 14.50% to 22.00%, flow index ranging 5.50% to 11.25% and plastic limit ranging from 11.07% to 15.38%, (Table: E-1; Appendix-E).

5.4.1.7 ELL Soil Series

This soil series represents loamy texture and it comprises sand ranging from 50.60 % to 51.50%, silt ranging from 21.40% to 32.80% and clay ranging from 16.60% to 27.10%, (Table: E-1; Appendix-E).

5.4.1.8 EUL Soil Series

The texture varies from sandy-loam to sandy-clay-loam in this soil series and it contains sand ranging between 63.70%-78.77%, silt ranging between 7.57%-16.30% and clay ranging between 13.70%-20.00%. It has liquid limit ranging between 24.46%-25.75%, flow index ranging between 4.00%-12.75% and plastic limit ranging between 7.28%-12. 42%, (Table: E-1; Appendix-E).

5.4.2 SOIL pH

The hydrogen ion concentration values of the soil series were measured in 1:2 soil: water suspension. All the soil series show hydrogen ion concentration values ranging between 7.25 to 10.50. The highest pH value 10.50 was recorded in village-Manikpur tehsil Sadabad and the lowest pH values were in village-pura of WUL soil series. The mean pH values of eight soil series are: 7.64, 7.95, 8.13, 8.23, 8.18, 8.15, 8.65, 8.58, respectively presented in figure-18 and tables: E-3 and E-4; (Appendix-E).

The major fluctuations in pH values are noticed in UL and WUL soil series. These variations in pH values are due to hydro-geomorphic conditions, local climate, micro-organism, hydrochemistry and soil characteristics. The major effect of these characteristics on pH values and their variations are observed in dry period, while in spring and winter it shows reverse conditions.

The area under cultivation is more in danger if the pH concentration increases slowly, then organic activities get slow down. It is revealed that the soil series with high sodium saturation have much higher pH values than those dominated by calcium and magnesium. This situation is of considerable importance in the study area of semi-arid ecosystem where the slick spots are observed and in progressive conditions.

5.4.3 Electrical Conductivity (EC)

The electrical conductivity expressed in dSm^{-1} for all the soil series and the highest EC values were recorded in UL soil series and the lowest in the YK soil series. These values range between 10.50 to 0.16 dSm^{-1}. The EC value decreases towards the bank of Yamuna river where the sandy soils are predominant in the epipedons. The mean EC values of these soil series are presented in figure-18 and table-E-3 (Appendix-E).

5.4.4 Cation Exchange Capacity (CEC)

This property, which is determined by the sum of extractable cations (Ca^{+}, Mg^{++}, Na^{+} and K^{+}) including extractable acidity (H) by using standard techniques, all these cations expressed in milliequivalents per 100 g of soil (Marrie, *et. al.*, 1982). Those series having fine-textured soil in north-eastern part and low-lying areas tend to have higher CEC than coarse-textured soils in north-western part. The CEC variations among soil series are due to the textural variation, humus content and moisture content. These variations in CEC are owing to the physico-chemical behaviour of soil series, which revealed that the CEC in some soil series increases with pH values (Figure-18). At a very low pH value the CEC is also low on account of NPK and organic content in fertile soil. The CEC is higher in saline/sodic soil series while the CEC is lowest recorded in TYK and WUL soil series, which ranges from 8.25 -to- 14.30 and from 8.25 -to-

9.7 respectively. It increases in fine texture soil and the maximum value recorded is 25.50 in UL soil series. The values are given in tables: E-3 (Appendix-E) and 9. In general, Cation Exchange Capacity Corresponds with fine textured soil in which clay content percentage is high.

5.4.5 Exchangeable Sodium Percentage (ESP)

The sodium hazards are expressed as exchangeable sodium percentage. It is an important characteristic of saline-sodic soil series in the area (Tables: E-3 and E-4; Appendix-E). The presence of high sodium content is an exchangeable form and has a detrimental affect on physico-chemical properties of soil. The high ESP content in root zones has direct effect on plant growth. The detrimental effect of ESP has been observed in S_1ans S_2 soil categories (Figure-15) in the area where the vegetation growth are scattered with less chlorophyll, low cycle growth of vegetation conditions.

5.4.6 Salinity and Sodicity

The salinity and sodicity of the soil and their aerial distribution are shown in the maps (Figures: 14 and 15). Salinity and sodicity were evaluated in terms of Hydrogen Ion Concentration (pH), Exchangeable Sodium Percentage (ESP), Cation Exchange Capacity (CEC), Electrical Conductivity (EC) and morphological characteristics of the soil and other parameters. These parameters are presented in E-3 and E-4 (Appendix-E). The high values of these parameters in soil samples indicated the existence of salinity-sodicity. This was observed in the village Manikpur tehsils Sadabad and other places in the form of irregular small and big patches of white encrustation of salts.

The salinity-sodicity of soils in the area are classified on the basis of high, pH, ESP, EC, and fine texture soil, their values are: 8.80, 14.12, >15 and 25.50 recorded respectively under UL soil series. There quantitative values are in tables: E-3 and E-4 (Appendix-E) and the maps presented in figures: 14 and 15.

5.5 Land Capability Class, Land Irrigability Class and NPK Distribution

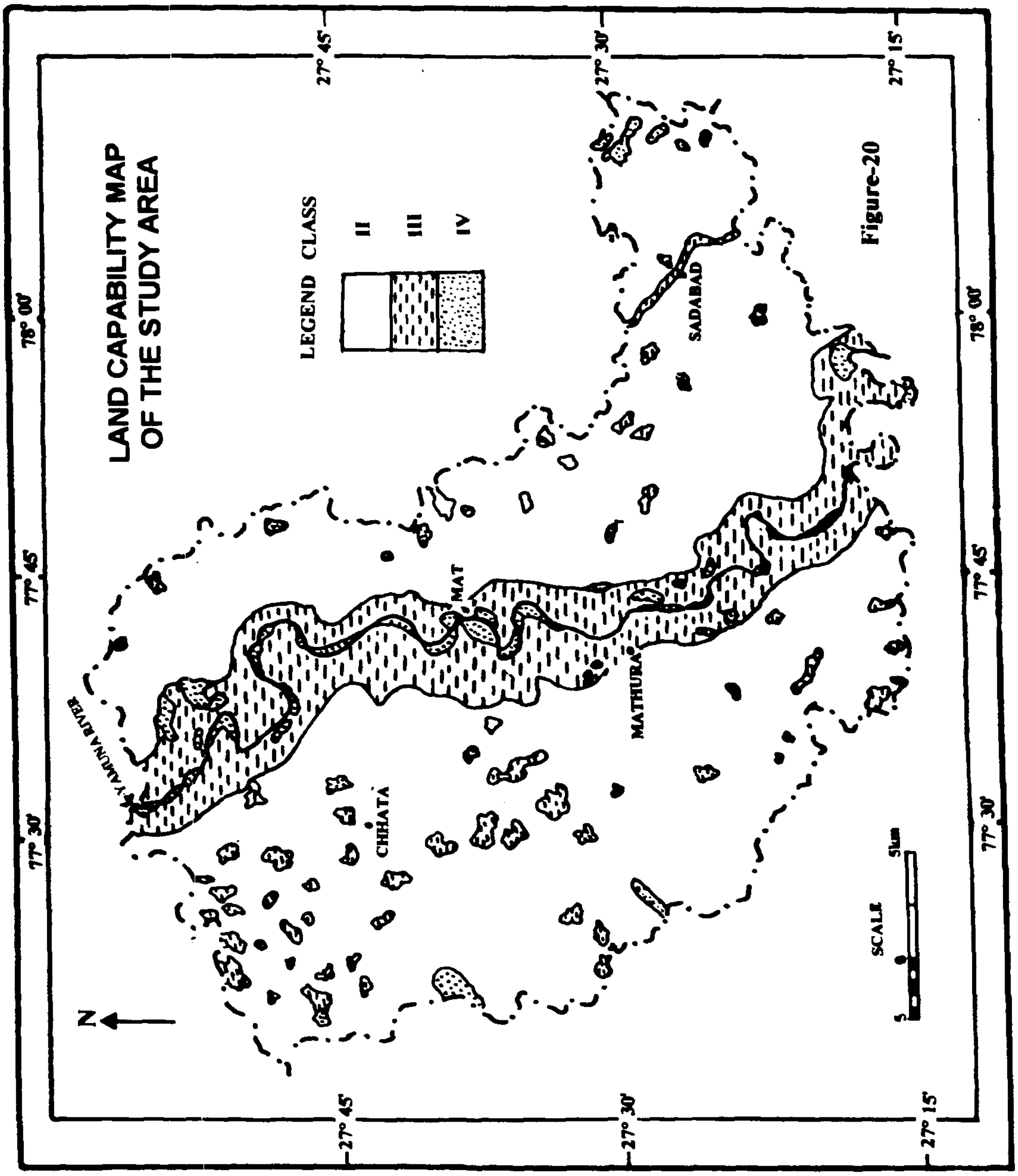
This section of the chapter describes the land capability class, land irrigability class and NPK distribution of the soils found in area. These characteristics of soil are very important to know the fertility status of soil for future use.

Land capability of the soil in the area mainly depends on the slope, soil characteristics i.e. soil depth, texture, structure, soil erosion, granules, salinity, wetness and drainage condition (including depth of water-table), (Brady, 1984). On the basis of these soil parameters land capability classes are identified.

Land irrigability classes were determined for the soil in the area, on the basis of soil condition. The parameters used for determining soil condition are effective soil depth, texture of surface soil, soil permeability, available water holding capacity, coarse fragments, gravel and *kankars*, salinity, salt-affected area and ESP (Brady, 1984). Land conditions were identified in terms of topographic slope and drainage.

Moreover, NPK distribution is based on the guidelines for nutrient levels for application of fertilizers for various parts of the study area. These guidelines are published by soil survey unit, Department of Agriculture, Government of U.P. for the local farmers to decide about application of fertilizers in different soils (Anon, 1986) and are given in tables: D-3 and D-4 (Appendix-D).

Land capability classes, Land irrigability classes and NPK distribution according to soil series are described in the following sections.


LAND CAPABILITY MAP
OF THE STUDY AREA
LEGEND CLASS
II
III
IV
N
YAMUNA RIVER
CHHATA
MAT
MATHURA
SADABAD
SCALE
5
0
5km
27° 45'
27° 30'
27° 15'
77° 30'
77° 45'
78° 00'
Figure-20

5.5.1 KK Soil Series

This soil series falls under land capability classes III and IV. (Figure-20) The soil corresponding to the IIIe and IVe is affected by moderate erosion. The soil of this capability class can be utilized for tree plantation, grazing practice, fisheries development and seasonal crops/cash crops, etc. Karban khadar soil series falls under land irrigability class III and IV and has poor drainage with shallow water table conditions (Figure-21).

The range of Nutrient Index for NPK distribution in this soil series is Nitrogen (N) 1.8 -to- 2.6, Phosphorous (P) 1.8 -to- 2.6 and Potassium (K) 2.7 -to- 4.2 in table D-3 and D-4 (Appendix-D).

5.5.2 YK Soil Series

This soil series falls under land capability class III and IV and have gentle to moderate slope, deep soils are fairly satisfactory texture and structure (Figure-20). This is affected by moderate erosion, wetness and salinity / alkalinity hazard and have been subdivided into IIIe, IIIw and IIIs. This soil series belongs to land irrigability class III and IV (Figure-21). It has gentle to moderate slope, poor drainage and shallow water - table conditions, presence of *Kankars* and gravels. This soil series can be used for limited cultivation, intensive grazing, wildlife and forestry, etc.

The fertility status indicated that it has the range for Nitrogen (N) 1.8 -to- 3.4, Phosphorus (P) 1.8 -to- 3.4 and Potassium (K) 3.5 -to- 4.2 are presented in tables D-3 and D-4 (Appendix-D).

The soil series can be utilized for limited cultivation, intensive grazing, wildlife, forestry seasonal crops and cash crops such as watermelon, muskmelon, melon-pumpkin and vegetables, etc.

5.5.3 TYK Soil Series

This soil series falls under land capability classes III and IV (Figure-20) and have gentle to moderate slope deep soil of fairly satisfactory texture and structure. The soil is affected by moderate erosion, wetness and salinity/alkalinity hazards and have been sub-divided into three sub-classes: LCC IIIe and IVe for the soil affected by erosion hazards: LCC IIIs and IVs for soil affected by salinity / alkalinity and LCC IIIw and IVw for soil affected by wetness.

This soil series falls under land irrigability class III and IV characterized by silty-clay-loam, clay-loam texture with *Kankars* (Figure-21). This soil series has *Kankars* and gravels, moderate salinity, gentle to moderate slope, poor drainage and water table conditions are shallow. This soil series can be used for moderate to limited cultivation, intense grazing, wildlife and forestry.

The fertility status of Trans-Yamuna-Khadar soil series suggested the range for Nutrient Index for NPK distribution in the soil. It has Nitrogen (N) < 1.8, Phosphorus (P) < 1.8 and Potassium (K) 2.7 -to- 4.2 can be seen in tables: D-3 and D-4 (Appendix-D).

This soil series can have moderate to limited cultivation, intensive grazing, wildlife and forestry, etc. Soil of this series can also be utilized for the cultivation of paddy, sugar cane, wheat barley, grams and pulses, etc.

5.5.4 UL (Saline/Sodic) Soil Series

This soil series is scattered, irregular small and large patches were spread in the study area and it falls under land capability classes III and IV (Figure-20). The soil of this land capability class can be utilized for *Eucalyptus* plantation, fisheries development and salt resistant vegetation, etc.

This UL soil series falls under land irrigabilty class III and IV (Figure: 21) the range for Nutrient Index for NPK distribution in this series is Nitrogen (N) <1.8, Phosphorus (P) 1.8 -to- 2.6 and Potassium (K) 1.8 -to- 3.4 are given in tables: D-3 and D-4 (Appendix-D).

The species of shrubs, grasses, trees and other salt resistant plants can be grown in UL soil series. Some of the major species are: Karnal grass (*Diplachne fusca*), Rhodes grass (*Chloris gayana*), Para grass (*Brachiaria mustica*), and Bermuda grass (*Cynodon dactylon*), Eucalyptus, Prosopis juliflora and Acacia nilotica. These species of grasses and plants are highly tolerant to saline and sodic soils. This soil has scanty patches of cultivation or it remains barren.

5.5.5 WLL Soil Series

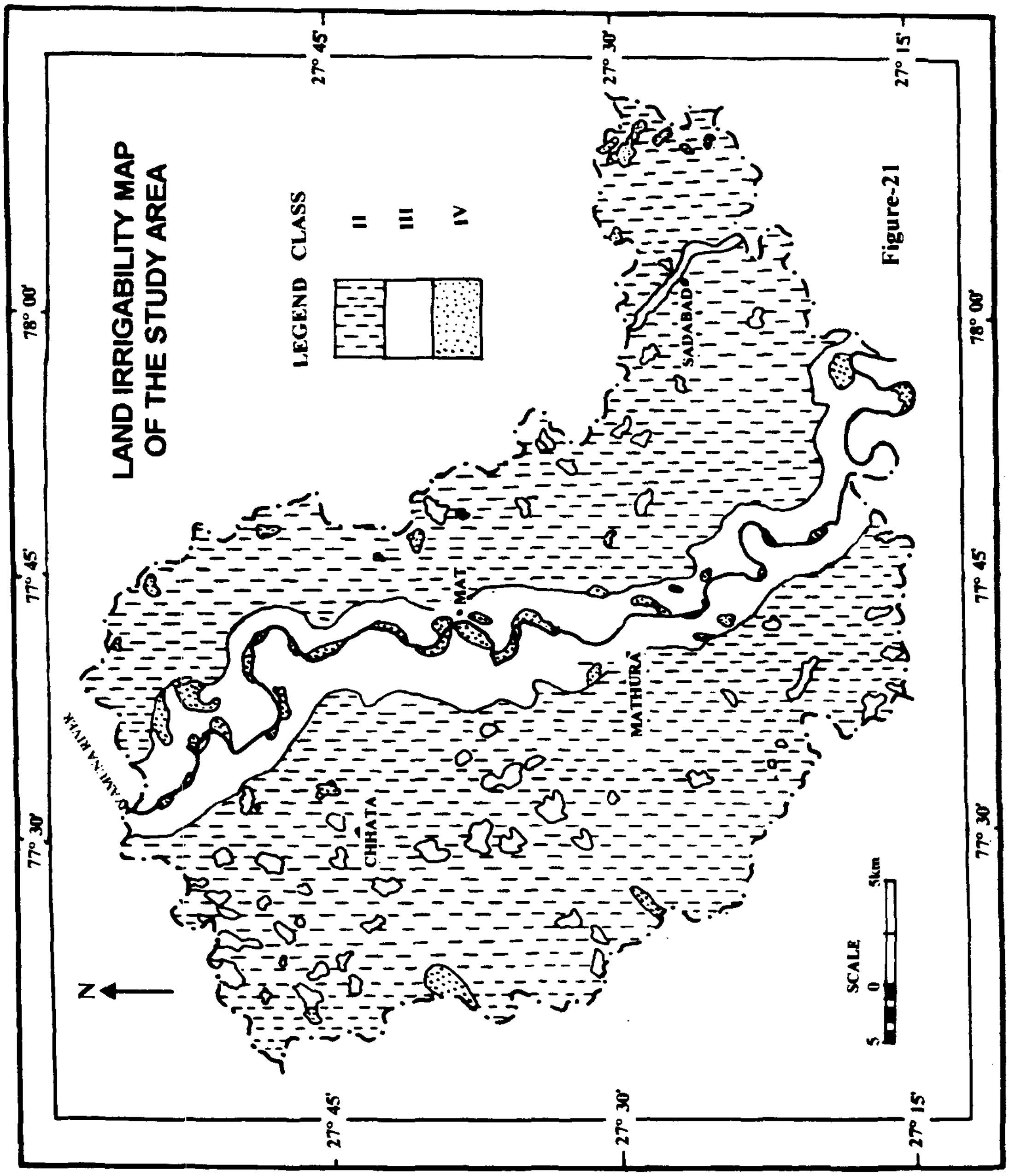
This soil series falls under land capability class II (Figure-20) the soil is fertile in nature and is free of natural hazards. The land use over this soil series is mainly cultivation, however it can also be put to other uses like grazing practice, forest development, etc. This soil series belongs to the land irrigability class II (Figure-21) and the range for Nutrient Index for NPK in this soil is Nitrogen (N) 1.8 -to- 3.4, Phosphorous (P) 1.8 -to- 3.4 and Potassium (K) 2.7 -to- 4.2 are presented in tables: D-3 and D-4 (Appendix-D).

In this soil series, some of the cash crops, vegetables and seasonal cultivation can be grown viz. paddy, wheat, barley, rye and pulse, etc. This soil series can also be used for intensive agriculture, intensive grazing, wildlife and forestry, etc.

5.5.6 WUL Soil Series

This soil series falls under land capability class II (Figure-20) and is fertile in nature, free of natural hazards, which aids for good agricultural production.

This soil series corresponds to land irrigability class II (Figure-21) and supported good conditions for cultivation. While the range of Nutrient Index for NPK distribution for WUL soil series is Nitrogen (N) 1.8 -to- 3.4m, Phosphorus (P) 1.8 -to- 3.5 & Potassium (K) 3.5 -to- 4.2 can be seen in tables: D-3 and D-4 (Appendix-D).


LAND IRRIGABILITY MAP
OF THE STUDY AREA
LEGEND CLASS
II
III
IV
N
SCALE
5 0 5km
CHHATA
MAT
MATHURA
SADABAD
Figure-21
27° 45'
27° 30'
27° 15'
77° 30'
77° 45'
78° 00'

Land capability and land irrigability are similar as mentioned in EUL soil series for cultivation, grazing, wildlife and forestry, etc.

5.5.7 ELL Soil Series

This soil series is wide spread in the study area and falls under land capability class II (Figure-20) and land irrigability class II (Figure-21). It has poor to fair drainage with shallow water table conditions. The range for Nutrient Index for NPK in the soil series is Nitrogen (N) 1.8 -to- 3.4, Phosphorus (P) 1.8 -to- 3.4 and Potassium (K) 3.5 -to- 4.2 are shown in tables: D-3 and D-4 (Appendix-D).

This soil series has land capability and land irrigability for the cultivation, grazing and forestry.

5.5.8 EUL Soil Series

This soil series falls under land capability class II (Figure-20) and soil is fertile in nature, free of natural hazards, which is suitable for good agricultural production.

This soil series corresponds to land irrigability class II (Figure-21) characterized by sandy-loam, loam and silty loam in texture, gentle slope and supports good conditions for cultivation. The range of Nitrogen Index for NPK for Eastern Upland soil series is Nitrogen (N) 1.8 -to- 3.4, Phosphorus (P) 1.8 -to- 3.4 and Potassium (K) 3.5 -to- 4.2 are presented in tables: D-3 and D-4 (Appendix-D).

This soil series has capability for crops, vegetables, and cultivation namely: wheat, barley, sugar-cane, millet, sorghum, grain, mustard, pea and potato, etc. This soil can use for intensive agriculture, intensive grazing, wildlife and forestry, etc.

5.6 Morphological Study of Soil Profiles

In this section the characteristics of selective soil profiles of different units from the study area have been carried out. These characteristics are to define the vertical exposure and their morphological variation in a soil as seen in its surfacial portion of the earth crust, that includes all the layers of the different physical, chemical and biological characteristics, that have been pedogenically altered the colour, texture and composition, etc. This alteration took place during period of soil formation and also deep layers that influenced pedogenesis during the Quaternary era. Boul *et. al.*, (1980) have also described the similar view in their work for soil profile's morphology.

In profile morphology, the soil layers, refers to as horizons, have thickness varying from a few centimeters to a meter or more. The eluviation, illuviation processes and other activities controlled the development, arrangement and combinations of these layers / horizons (Ahmad, 1994). The essential medium in the development of these profiles is water which aids in transference and reconstitutions of soil profiles in the study area.

Brady (1984) described the well development profiles and have divided into five principal horizons viz. O, A, E, B, and C horizons. A-horizon, pure organic matter (O Horizon) lies above the A-horizons. The A, E and B horizons represent a partly weathered layer of parent material from which the solumn has been divided. Each horizon may, further be sub-divided into sub-horizons such as O_1, O_2, A_1, A_2, ..., etc.

Figure-22 Profile shows the important horizons and sub-horizons for profile description (Brady, 1984). For the study of profiles and its description in the present era. It is essentially pre-requisite for planning and management of the agriculture of this planet to maintain a sustainable green ecosystem.

Morphologically, the representative soil profile of the study area were collected from eight different described soil series, based on visual variation. These soil series are varied from each other and their general physico-chemical characteristics have been described in Chapter-5.

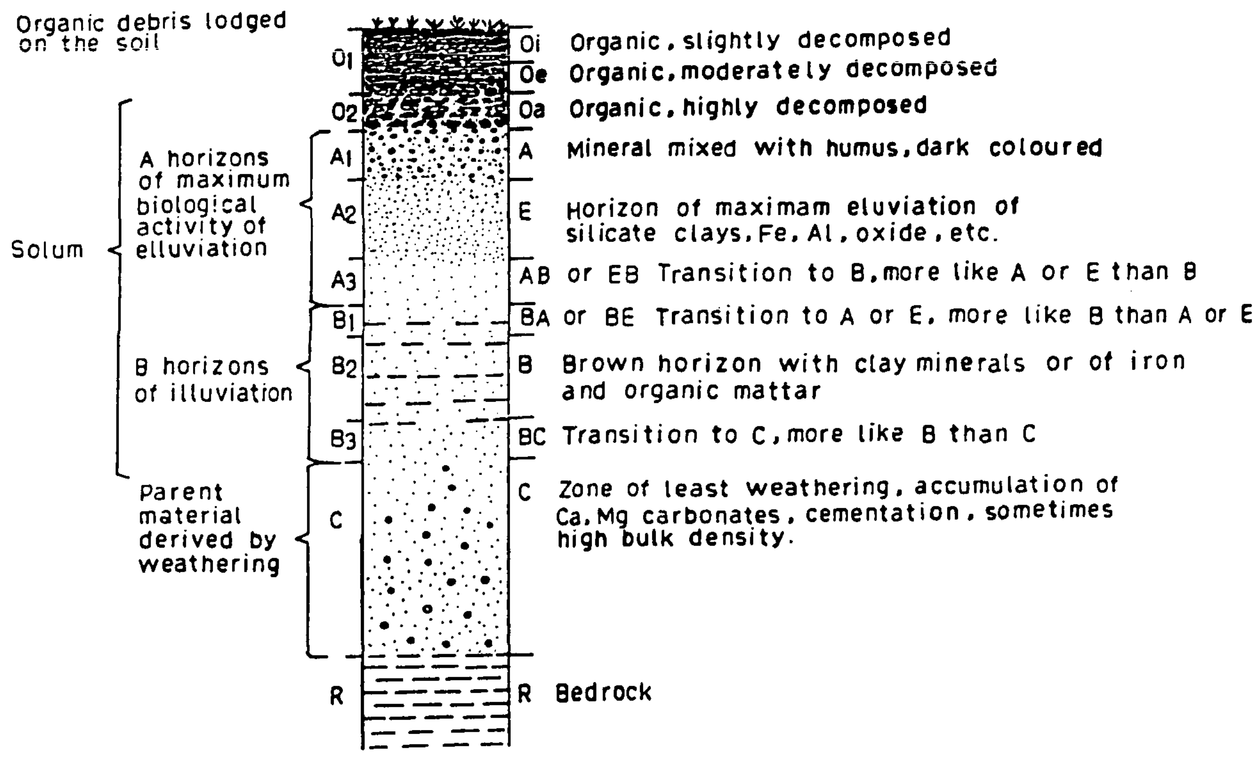


Figure-22 Schematic Diagram of a Hypothetical Soil Profile, Showing Principal Horizons and Sub-horizons.

After Brady (1984) and Ahmad (1994)

These representative soil profiles were examined after pre-field visual interpretation of remotely sensed data as discussed in Chapter-4.

This chapter gives the morphological characteristics of eight representative profiles (Figures: 23(a -to- d) and 24(c -to- h). The morphological characteristics of horizons/layers were recorded. Later on, morphological characteristics of these profiles were determined to suggest the behaviour of healthy root crops, erosion control and profitable agriculture production.

5.6.1 Comparative Analysis of Soil Matrix with Munsell Colour Chart

Generally the melanisation and leucinisation of the soil in the study area is not uniformly spread and varies from place to place. The dominating colours of each horizon are described for eight soil profiles are presented in Appendix-A; tables: A-1 -to- A-8.

The dominating soil colours in the study area were noticed in the field as well as in the laboratory by using the Munsell soil colour chart along with designation are used to describe the soil colours of each horizon of the soil profiles, while munsell colours and designation of surface soil are also presented in tables: E-1 and E-2 (Appendix-E).

5.6.2 Texture

The textural studies of soil profiles were carried out by proportional particle size analysis (Chapter-5). The particle size distribution in the study area show that the sandy soil is more dominating in north-western part, while clay soil was found in the north-eastern part of the study area.

The textural variations within the profiles are the result of sedimentary deposits and are laid down in horizons, one on the top of the other. These variations in textural proportion are more or less well marked in magnitude of chemical composition, grain size, colour, plasticity and some other characteristics.

In the field observation, the colours of the soil horizons show the stratification either wavy or irregular and sometime horizontal.

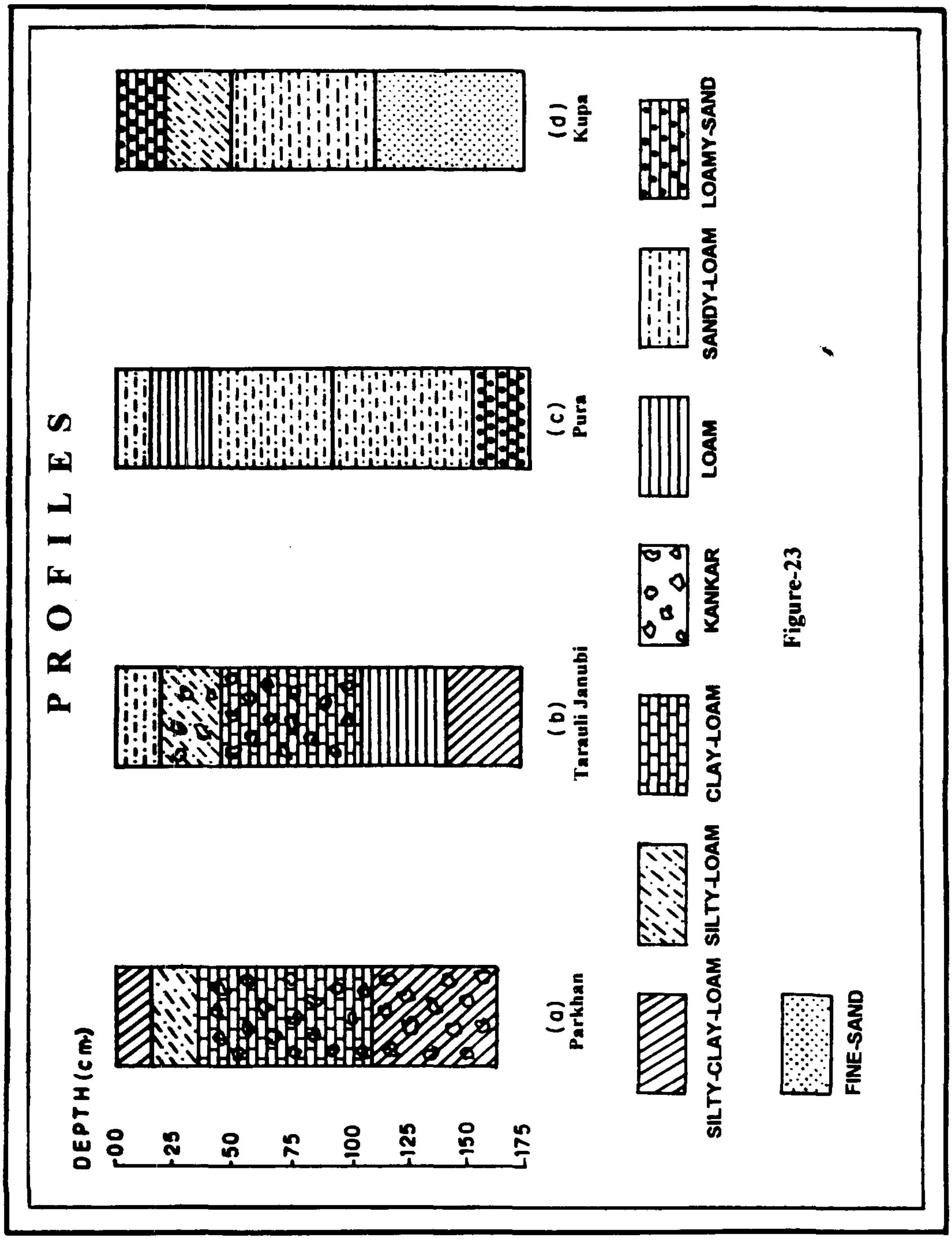
The colour stratification represents the textural class that varied in the epipedon and deeper horizons, namely: silty-clay-loam, silty-loam, clay-loam kankar (*nodules*), loam, sandy loam, loamy-sand, fine-sand and sand.

The sandy soil shows the small grains, mostly of quartz, flaky micaceous mineral and angular to sub-angular and platy fragments in the epipedon. The fine texture soil such as clay consists of minute crystalline particles together with detrital grains and retain enough moisture, plasticity and stickiness. However, porosity, permeability and infiltration capacity were less.

The Kankar (*Nodules*) of different sizes were seen on the surface and in between various horizons as well as within the root zones due to redentary processes.

During field checks and Radiometric measurements of reflectance from the study area, the black *kankars* of varied size were seen on the surface of sodic soil, which is located near Manikpur village in tehsil Sadabad, showing the characteristics of textural classes with depth of the profiles, while surface soil texture characteristics are presented in tables: E-1 and E-2 (Appendix-E).

Texturally, soil varied from sandy loam in epipedon to loam, clay-loam and sandy-clay-loam in the deeper horizon. Fine clay gradually increases with depth (Appendix profile into IV, Table: 4-A). Except this profile, the rest profiles show fine texture soil occurring at a depth greater than 60 to 70 cm. this indicates accumulation of illuvial fine clay in the form of argillacious in these soils. The silty-clay soils are generally narrowed down in the B-horizon to C-horizon.


PROFILES
DEPTH (cm)
00
25
50
75
100
125
150
175
(a) Parkhan
(b) Tarauli Janubi
(c) Pura
(d) Kupa
SILTY-CLAY-LOAM
SILTY-LOAM
CLAY-LOAM
KANKAR
LOAM
SANDY-LOAM
LOAMY-SAND
FINE-SAND
Figure-23

5.6.3 Structure

The structure variation in the soil were noticed on the basis of shape of aggregates, size and their arrangement in the profiles. The soil profile nos. I, II, III, and IV having, platy, crumb, angular to sub-angular, structure while other remaining profiles have spheroidal, angular to sub-angular, granules and prismatic structures (Appendix-A).

Thus, the two distinct structural sequences are found: (a) Platy, angular/sub-angular-massive and (b) angular blocky, massive. These sequences occur in the soil profiles, which are collected from the salt-affected soils. Similar types of structure sequences were observed by the Bhargava and Abrol (1978) in their studies for Indo-Gangetic alluvial plain. Generally, the massive characteristic of soil is there in the study area within the zone/pockets of precipitation of calcium carbonate and mangniferous concentration in the soil profiles.

5.6.4 Calcic Horizon

This horizon was formed by precipitation of sedentary accumulation of calcium carbonate in the form of irregular shape. The shape of concentrations commonly referred to as 'Kankars' (*Nodules*) occurring in the soil. These ***kankars*** in the sub-soil were existed at a shallow depth of about 26 cm below the 'A' horizon in profile no. IV and V can be seen in Appendix-A (Figure: 23, Profile: a and b) while the deepest profile no. VIII is presented in Appendix-A (Figure: 24(g)) in soil series ELL occurring at a depth of 45 cm., while the rest of the soil profiles usually not shown these concretions up to depth of 180 cm. The scattered calcic horizon has mixed textural classes which does not show any concretions of carbonate or silica content in the root zone through the interconcretionary space filled with the precipitated fine soil material.

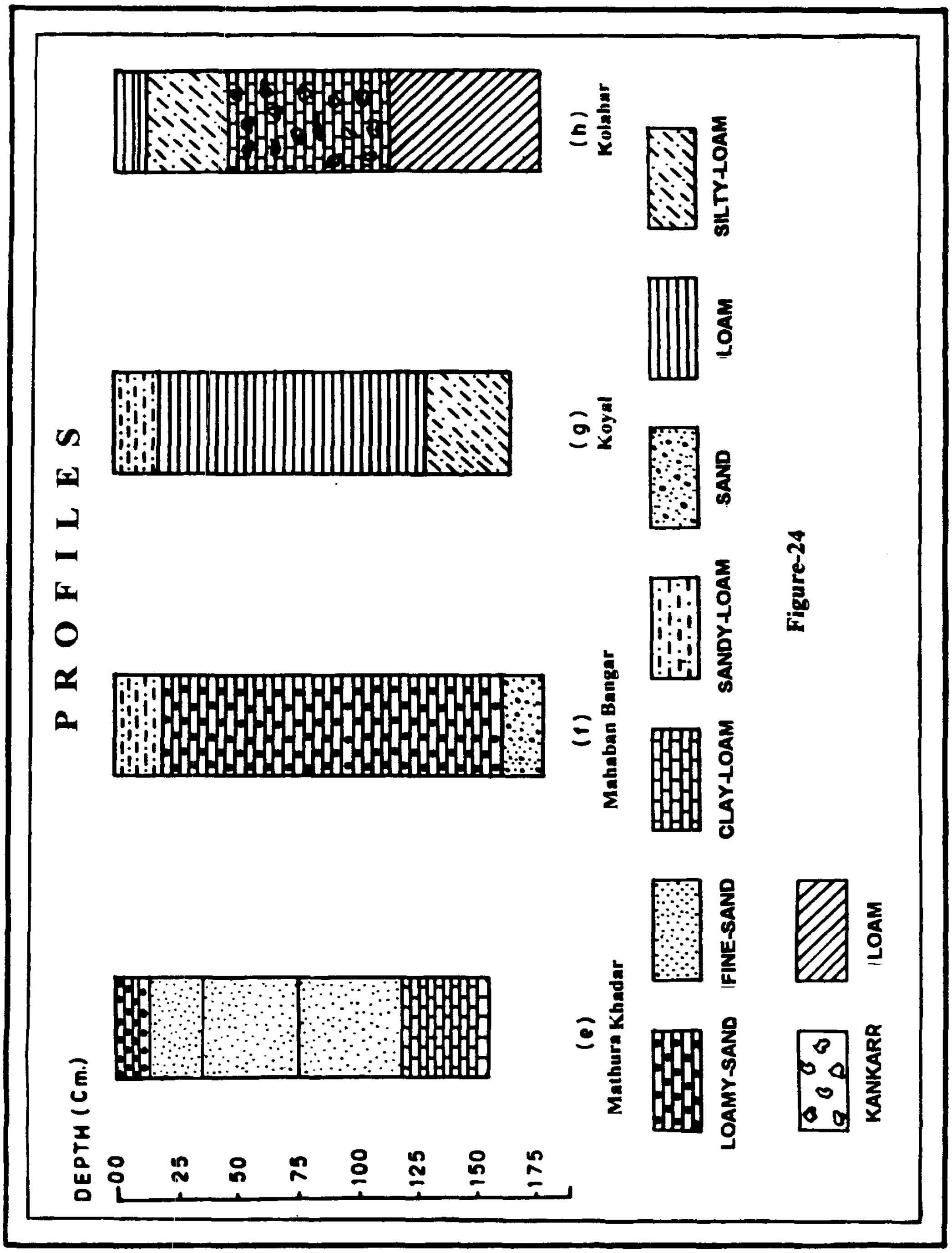

PROFILES
DEPTH (Cm.)
00
25
50
75
100
125
150
175
(e)
Mathura Khadar
(f)
Mahaban Bangar
(g)
Koyal
(h)
Kolahar
LOAMY-SAND
FINE-SAND
CLAY-LOAM
SANDY-LOAM
SAND
LOAM
SILTY-LOAM
KANKARR
LOAM

Figure-24

5.6.5 Iron Manganese Concretions

The concretions of this kind occurred in all the salt-affected soil invariably above the calcic horizon or even on the surface. These types of concretions were seen at Manikpur village, Sadabad tehsil. The concretions of black kankar of varied sizes were noticed on the surface of sodic soil at shallow depth of 10 cm. and 14 cm. These black *kankars* were found on the soil surface due to the erosion of surrounding less resistance as well as soluble material that washed away during rainy month.

5.6.6 Calcium Carbonate

The maximum accumulation of $CaCO_3$ concentration is encountered in the calcium horizon i.e. Kankar (*Nodules*), which can be seen in figure-23 (Profiles: a & b), and in figure-24 (Profile-h). The concretions larger than 2mm varied from 12.6 per cent in profile-h -to- 46.9 per cent in profile-a. Concretion finer than 3mm of $CaCO_3$ showed increasing trend with depth in UL, ELL, WLL representative profiles (Appendix-A). The concentration of $CaCO_3$ is on account of fluctuation in water-table conditions and shallow aquifer, which play a major role in formation of scattered $CaCo_3$ accumulation in the horizon.

5.6.7 SOIL pH

Soil in the area shows high pH values ranging between 7.82 -to- 10.40. In A-horizon, profile nos. I -to- VIII (Appendix-A) in the epipedons have the highest pH values which tend to decrease gradually with depth. In WUL and EUL soils have lower pH values (Appendix-E; Tables: E-3 and E-4).

5.6.8 Electrical Conductivity (EC) of the Saturated Extract

The EC values are shows in figure-18 (Tables: E-3 and E-4; Appendix-E). The highest EC values were recorded in S_2 soils, 18.40dSm^{-1} in epipedons, while S_1 soil having 14.12Sdm $^{-1}$ and other remaining profile have less EC i.e., more than 0.18 and less than 14.12 dSm^{-1}. The EC values decreases with depth in all the profiles excepts UL soil series.

CHAPTER-VI

DIGITAL ANALYSES OF SATELLITE DATA

DIGITAL ANALYSIS OF SATELLITE DATA

6.1 General Statement

Machine based automatic classification is the ultimate target of image processing in remote sensing. In the visual image analysis interpretation of an image is done by a trained user of imagery. While in the digital classification, computer based processing is done using statistical procedure. The justification of automatic classification is due to various reasons. First of all an automatic classifier can be used by a non-trained person as well. Secondly this exercise can be repeated as per demand. Naturally automatic classification involves less cost. A good classification algorithm written in a comprehensive image analysis software is not the only requirement for automatic classification. It also requires either a properly processed image by an experienced person using the expertise of visual interpretation of themes on the screen or there should be proper guidelines available for image processing to a lesser trained user of automatic classifier. These guidelines are to be the result of a thorough study of a particular theme containing statistical theory based reasons for the use of particular technique of image processing such as choice of a principal component or choice of a transform, etc.

This work is concentrating or providing guidelines for image processing with soil as the main theme. To achieve the goal, this chapter discusses the use of image processing techniques using IRS-1A LISS-II, 4 band data with justification divided from visual discriminability to statistical theoretic reasons.

Gonzalez (1992) has mentioned some basic concepts of digital images. The image refers to 2-dimensional light-intensity function, denoted by f(x, y), where the value or amplitude of 'f' at spatial coordinates (x, y) gives the intensity of image.

As we know that the light is a form of energy, f(x, y) must be nonzero and finite

$$\text{i.e., } o < f(x, y) < \infty \qquad \text{...(i)}$$

The basic nature of f (x, y) is characterized by two components

(i) the amount of source of light incident on the scene being viewed and

(ii) the amount of light reflected by the objects in the scene, appropriately they are called the illuminated "i (x, y)" and reflected component "r (x, y)".

The function, i (x, y) and r (x, y) combine as a product to form

$$f(x, y) = f(x, y) = i(x, y) \; r(x, y) \qquad \text{...(ii)}$$

$$\text{where} \qquad o < i(x, y) < \infty \qquad \text{...(iii)}$$

$$\text{and} \qquad o < r(x, y) < 1 \qquad \text{...(iv)}$$

Equation (iv) indicate that the reflectance is bounded by "o" (total absorption) and "i" (total reflectance). The light reflected by an object is assumed to be approximately specific to that object. On the basis of these basic image concepts, the digital image data are utilized for digital image processing and various techniques for soil study.

6.2 Utilization of IRS-LISS II Data in Soil Studies

India's first operational remote sensing satellite IRS-1A, was successfully launched on March 17, 1988. Orbiting the earth in a north-south direction at an altitude of 900 Km. IRS-1A, has with it two payloads, LISS-I and LISS-II. Subsequently three more satellites- 1B, 1C and 1D have been launched.

These satellites are providing useful information for some of the key application areas such as soil, agriculture, water resources, mineral exploration, urban surveys, etc.

The data from LISS-II sensor provides a broad synoptic view of the earth's surface on a repetitive basis in four spectral bands ranging from

0.45 μm to 0.86 μm. The smallest area that the satellite sensor can observe is known as a pixel. The pixel size for LISS II is 36.25 m.

An image of the study area, (Plate-1) of May 11, 1989 of LISS-II sensor was acquired. The image data were transferred from floppy in band interleaved by line (BIL) format and converted to Intergraph compatible format using 'MGE' Image translator software on PC based Dell system of 1.2 at RSACREG, AMU, Aligarh.

6.3 Image Enhancement

For soil study, enhancement techniques are performed on the digital image data to improve the interpretability of the image by increasing apparent contrast or the visual distinction among the soil in an image.

Image enhancement concerns the modification of the image to improve its spectral quality. The criterion is subjective and the enhancement is judged by the observer. This technique is performed for soil study in the interactive processing.

The procedures of image enhancement are described by Hall (1979). One of these methods is the alteration of gray level values. The transformation may be linear, logarithmic transformation or exponential. The logarithmic transformation enhances low contrast detail, because logarithmic provides much detail at low digital differences.

The objective is to create new [g(x, y)] image from the original [f(x, y)] image data in order to increase the discernibility for better interpretation of the digital image data.

The image data are displayed interactively on a colour monitor and several enhancement techniques have been described in the following section to study the soil of Mathura district, U. P.

The image is displayed as a two-dimensional array for visual interpretation of spatial features such as size, shape, texture, linear features.

At present, the application of pattern recognition algorithms to soil resources data has not advanced operationally to the point where the spatial features are used as effectively as spectral features.

Enhanced digital image of IRS-1A, LISS-II is utilized in the present study, and various operations are applied to image data. These includes:

(i) Analysis of single band images,

(ii) False Colour Composite (FCC), IHS & IHS transformation images,

(iii) Filtered image, and

(iv) Principal Component Image (PCI) and other image pattern recognition techniques.

The spectral reflectance pattern in LISS-II image, bands: 1, 2, 3 and 4 are combined with other image processing techniques, which enable us to enhance image characters. In present study, the digital processing was performed using single band image analysis, Principal Component Analysis, Laplacian-II, High pass, Low pass, Prewitt, Edge sharpening and Gaussian filters, Colour compositing, Classification and finally IHS transformation, Intensity, Hue and Saturation images.

6.4 Interpretation of Single Band Images

The spectral information regarding soil and its associated features are spectrally extracted from the individual band data. There are four wavelength bands in IRS-1A LISS-II data in the form of image. These images represent EMR in the region of 0.45 μm to 0.86 μm. The individual wavelength are: Band-1 in the range of 0.45 μm to 0.52 μm, Band-2 image in region of 0.52 μm to 0.59 μm and Band-3 image in the region of 0.62 μm to 0.68 μm and Band-4 image representing 0.77 μm to 0.86 μm.

Table-8 represents the differentiation of soil units and other associated features on the single band image. Grading of enhancement in terms of well enhanced, medium enhancement, poor enhanced and subdued categories have been done for the comparison purpose.

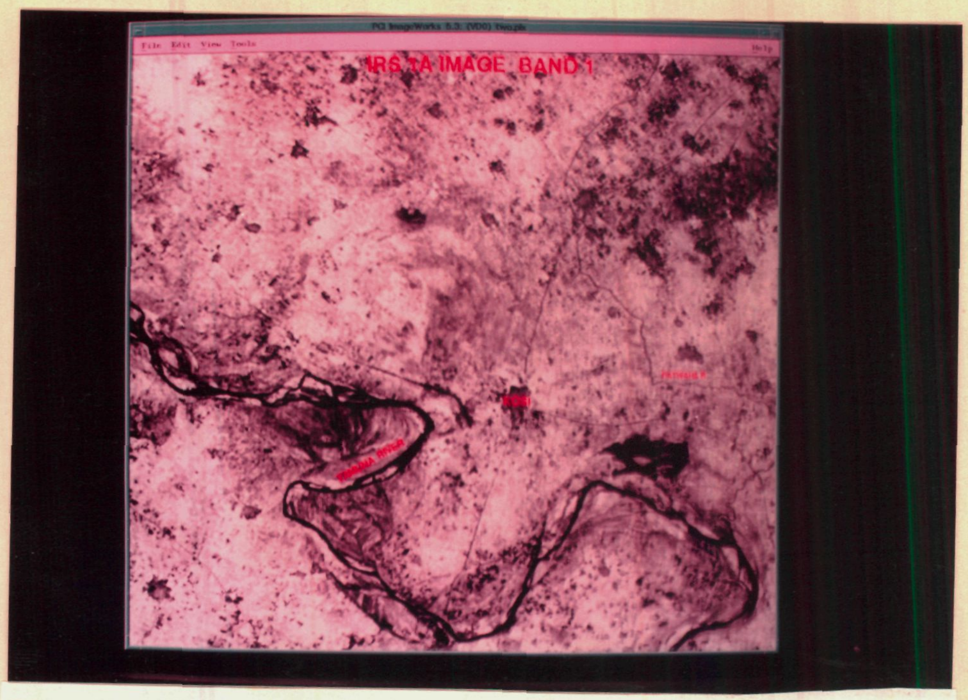


Plate-5 IRS-1A LISS II; Band-1 Image (Processed by V 5.3 EASI/PACE Software).

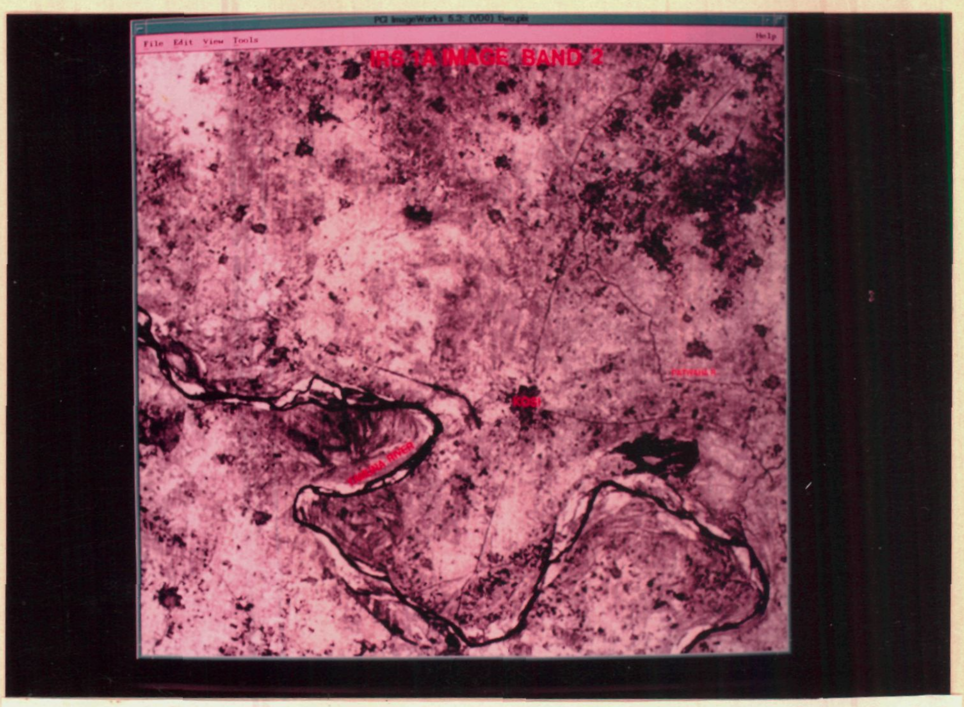


Plate-6 IRS-1A LISS II; Band-2 Image (Processed by V 5.3 EASI/PACE Software).

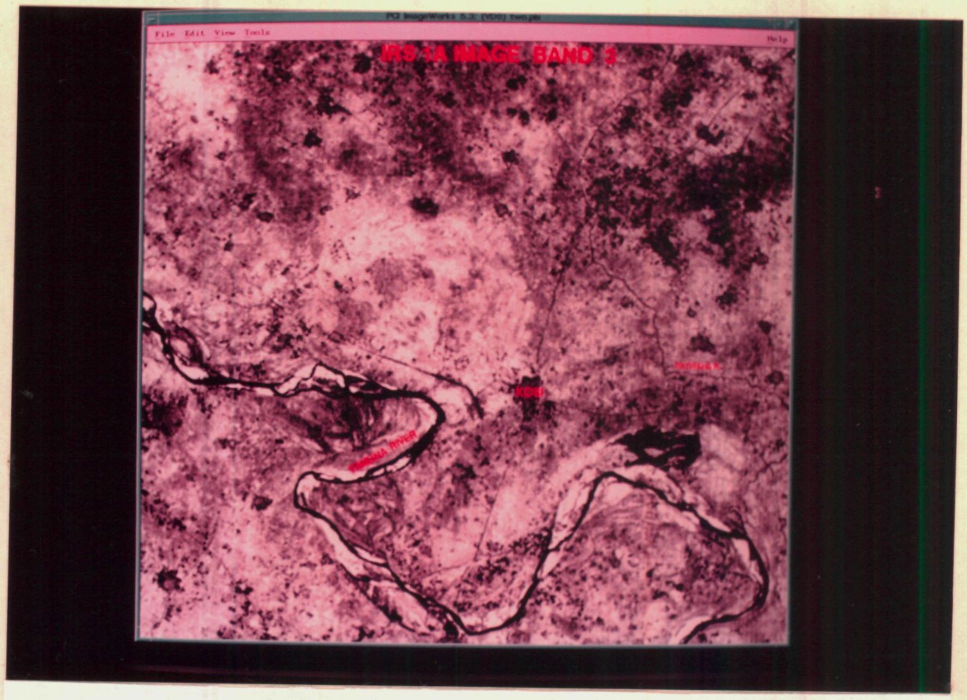


Plate-7 IRS-1A LISS II; Band-3 Image (Processed by V 5.3 EASI/PACE Software).

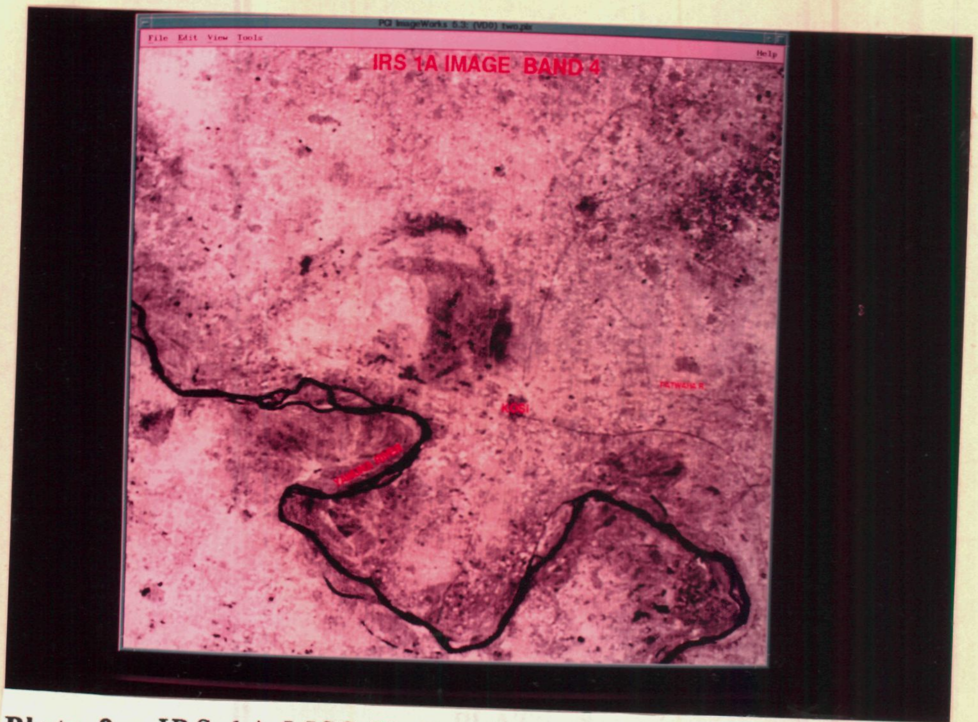


Plate-8 IRS-1A LISS II; Band-4 Image (Processed by V 5.3 EASI/PACE Software).

TABLE-8 Differentiation of Soil Units and other Associated Features on Single Band Images

S. No	Soil series & Associated Features	MGE Software Band No.				EASI / PACE Software Band No.			
		1	2	3	4	1	2	3	4
1	YK	Sub.	Well En.	En.	Poorly En.	M. En.	Well En.	Well En.	Sub.
2	TYK	En.	En.	Sub.	En.	En.	En.	M. En.	Well En.
3	UL	M. En.	En.	En.	M. En.	Poorly En.	M. En.	En.	Well En.
4	WUL	Poorly En.	En.	Poorly En.	Sub.	Poorly En.	Sub.	Poorly En.	M. En.
5	EUL	En.	En.	En.	Sub.	Poorly En.	En.	Sub.	Sub.
6	ELL	Poorly En.	Sub.	M. En.	Sub.	En.	Poorly En.	En.	M. En.
7	Geomorphic unit	Sub.	Well En.	Sub.	Sub.	Sub.	M. En.	En.	Sub.
8	Biomass	Poorly En.	Well En.	M. En.	Sub.	M. En.	Well En.	Well En.	Sub.
9	Water bodies	Well En.	Sub.	M. En.	M. En.	En.	Poorly En.	Sub.	En.
10	Settlement	Poorly En.	Sub.	Sub.	Sub.	M. En.	En.	En.	Poorly En.

Well En. – Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. - Subdued

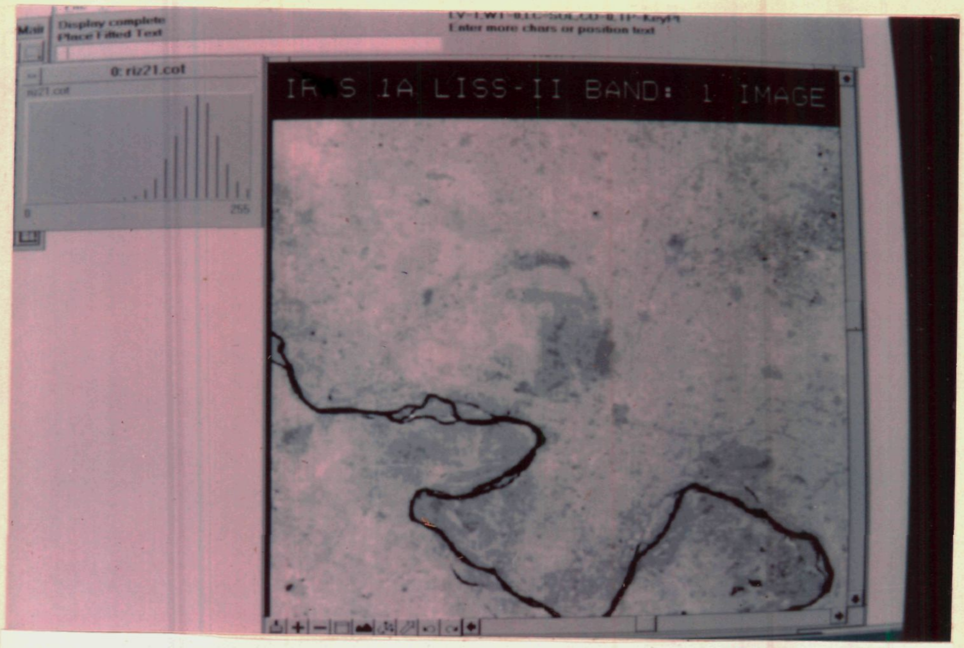


Plate-9 IRS-1A LISS II; Band-1 Image (Processed by 'MGE' Software).

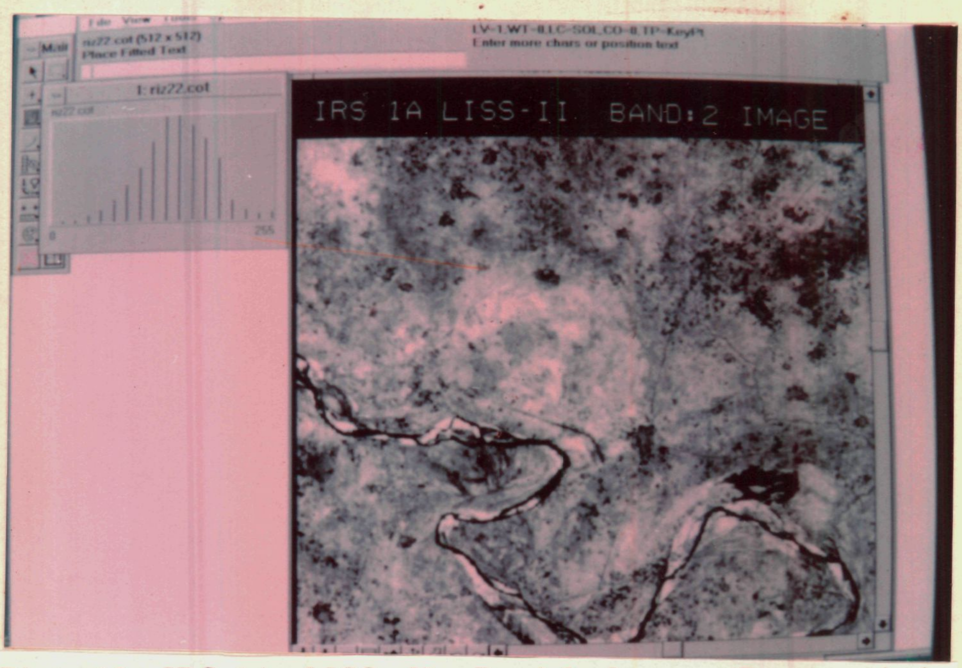


Plate-10 IRS-1A LISS II; Band-2 Image (Processed by 'MGE' Software).

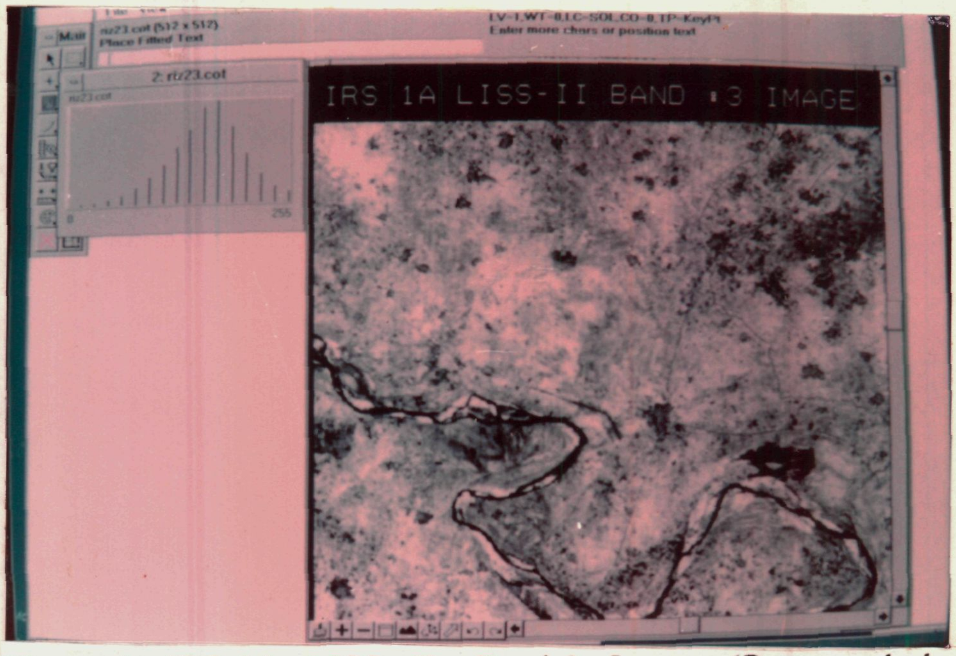


Plate-11 IRS-1A LISS II; Band-3 Image (Processed by 'MGE' Software).

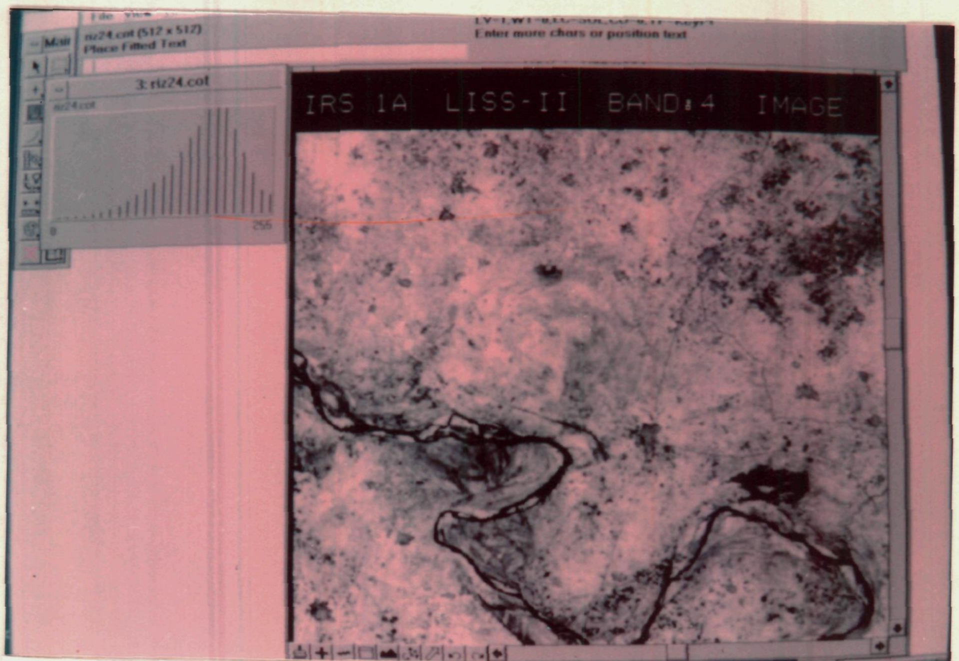


Plate-12 IRS-1A LISS II; Band-4 Image (Processed by 'MGE' Software).

As indicated in the Methodology chapter two softwares-MGE and EASI / PACE were used for the generation of enhanced single band image. The images of bands 1 -to- 4 on MGE software are presented in plates 9 -to- 12 and on EASI / PACE software in plates 5 -to- 8.

From the above table, it is clear that out of the six soil series that are seen in the extracted 512 × 512 pixel image, EASI / PACE software has generated better quality image enhanced product as compared to MGE.

In the EASI /PACE single band images, band 4 image provides best enhancement for a different soil series, followed by band 2, band 3 and band 1 may be termed as poor for single band differentiation of soils.

Among various other features on the image, geomorphic units are enhanced in band 2. Biomass (crops vegetation cover and forest) is well enhanced in band 2 and 3 and settlement is medium enhanced in band 1 image.

In MGE software, the single band images, band 2 provides best enhancement for different soil series, followed by band 1, band 4 and band 3 may be termed as poor for a single band differentiation of soils, while other associated features on single band image, viz. geomorphic units are well enhanced in band 2, biomass (crop, vegetation cover and forest) is enhanced in band 3, band 4 and band 2, while poor in band 1, and water bodies is well enhanced in band 1 and medium enhanced in band 3 and band 4, and settlement is poorly enhanced in band 1.

6.5 Principal Components Analysis (PCA)

PCA is a powerful method for change detection based on visual and statistical interpretation of digital images for soil covering the area of interest over Indo-Gangetic Alluvial Plain are examined.

This is a commonly applied techniques in remote sensing image analysis for image encoding and image data compression (Gonzales and Wintz, 1977), and image enhancement (Richards, 1993).

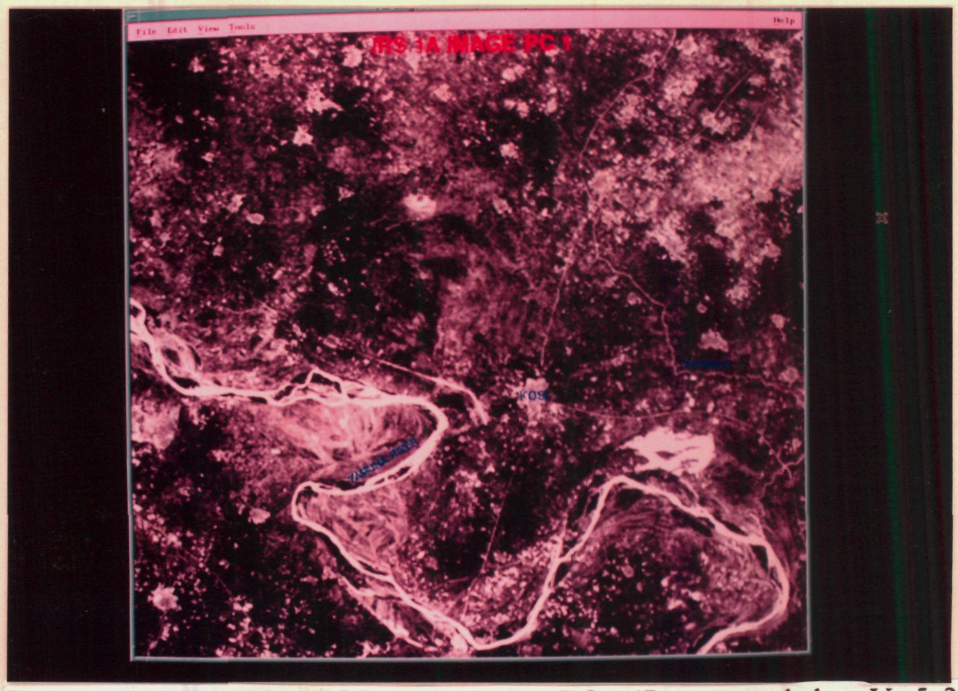


Plate-13 IRS-1A LISS II Image; PC_1 (Processed by V 5.3 EASI/PACE Software).

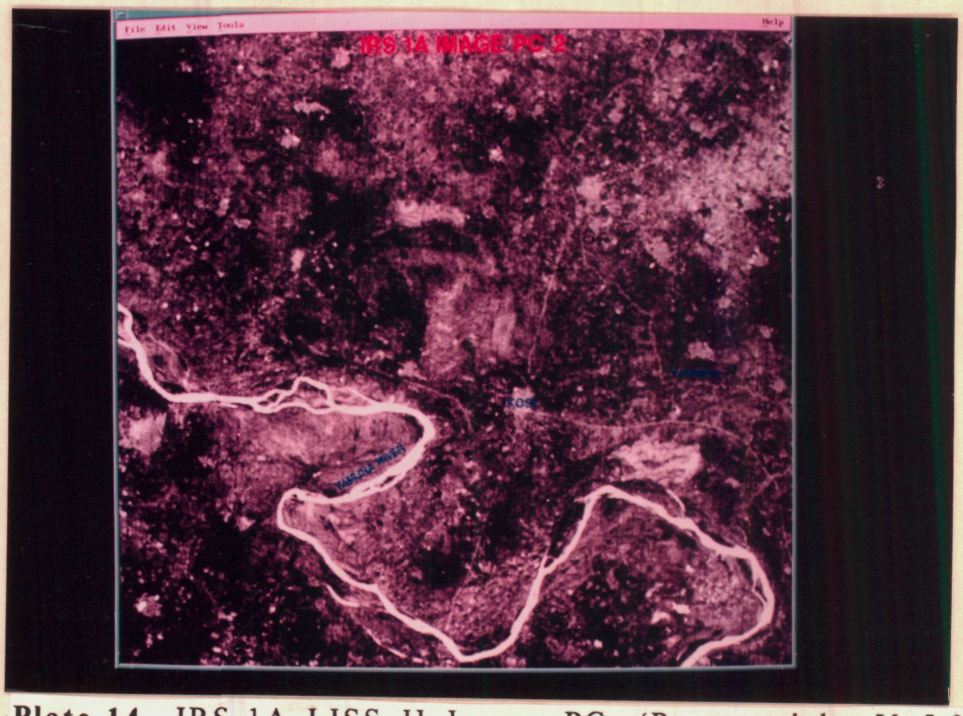


Plate-14 IRS-1A LISS II Image; PC_2 (Processed by V 5.3 EASI/PACE Software).

This is also a mathematical transformation that generate g(x, y) image referred to as axes, or components, which are linear combinations of the f(x, y) images offer a good source of details of soil resources and monitoring land degradation processes by Dwivedi (1996, 1992), Taylor, (1974), Ingerbritsen and Lyon (1985) and Jiaju, (1988).

Townshend (1984) gives the utility of Low order principal components and he found that "It seems to check PC images by eye, using ones knowledge of the area rather than rely solely upon figures for information content or on interference drawn from the PC loading".

The purpose of this techniques is to know spatial variation of surface soil units that presumed to exist within a set of multivariate observations, expressed as a pattern of variance and covariance between variables, where variability exists due to physico-chemical characteristics of soil. In general spatial and spectral variation within the image are also due to external condition, such as an atmospheric transmission, angle of solar incidence.

Images variations can also be identified due to spectral variations of different types of soil units and their associated features. Moreover, the interrelation of several physical, chemical and biological processes, causes different micro-climatic conditions within the study area.

The PCA technique has revealed the most reliable techniques to obtain significant results.

Principal component analysis (PCA) has been carried out to get soil characteristics enhancement by extracting the high quality information from the f(x, y) data.

Table-9 illustrate the differentiation of soil units and other associated features on Principal Component image using EASI / PACE software.

Table-9 revealed that the six soil series for grading of enhancement in terms of well enhanced, enhanced, medium enhanced, poor enhanced and

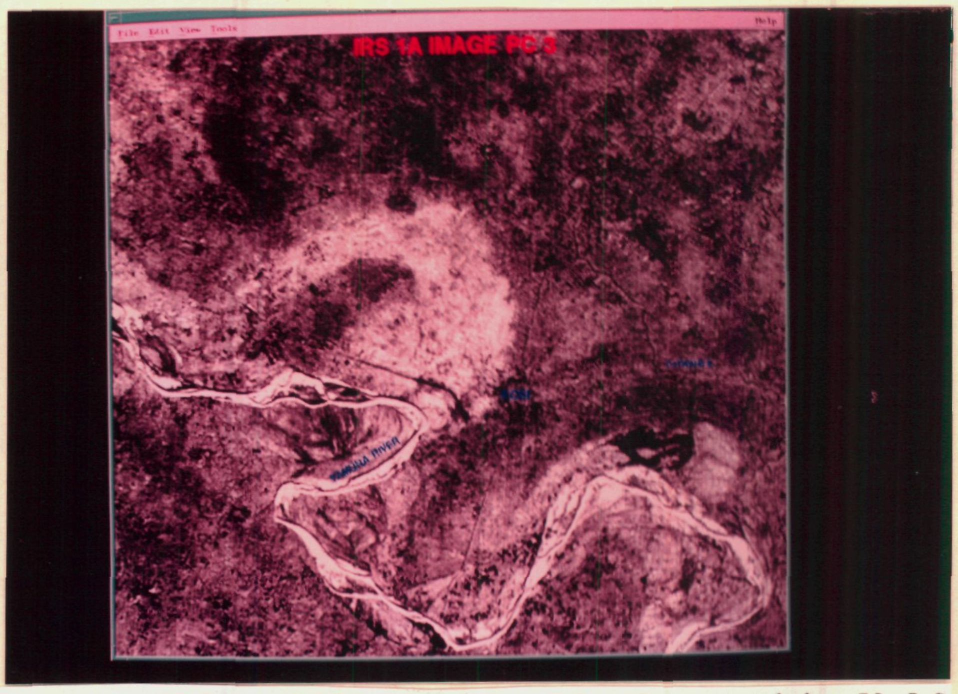


Plate-15 IRS-1A LISS II Image; PC_3 (Processed by V 5.3 EASI/PACE Software).

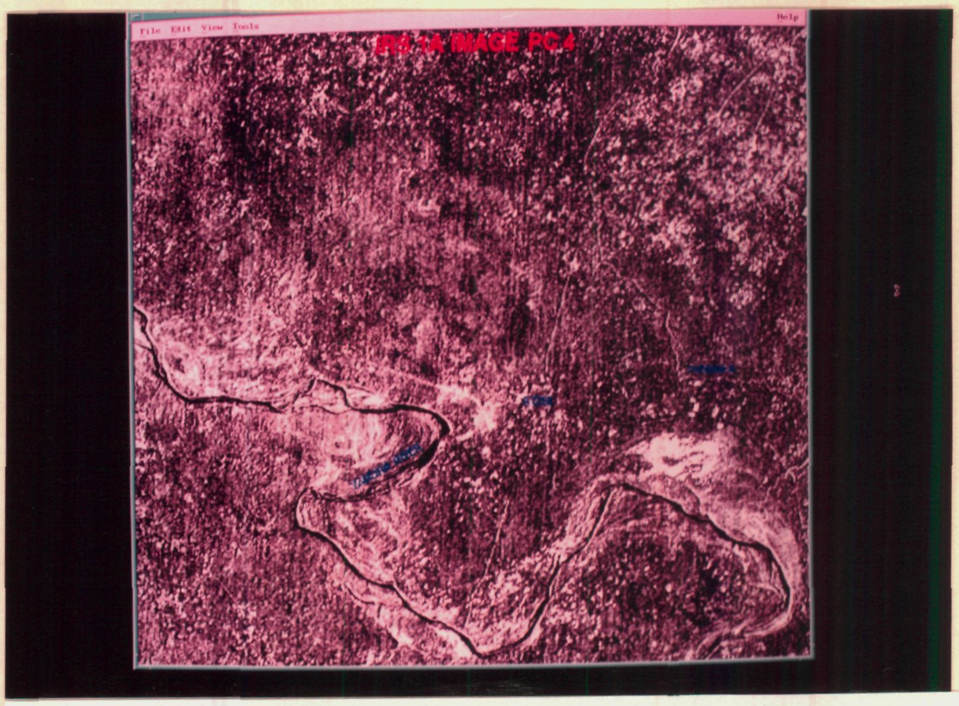


Plate-16 IRS-1A LISS II Image; PC_4 (Processed by V 5.3 EASI/PACE Software).

subdued. These grading represents the image enhanced and subdued statistics for the soil series.

PC2 image provides best enhancement for soil units, followed by PC1, PC3, while PC4 represents poor spectral information for different soil series, most of the information in PC4 image is subdued.

However, other features, viz., Palaeoscar, Channel bar, Point bar, Meander scar are well enhanced in PC1, PC2, and PC3, while these information are subdued in PC4 image.

PC1 and PC2 images are significant for deciphering soil series and enhancement, which are given in table-9, while YK and EYK series are well enhanced in PC1, TYK is well enhanced in PC2 image and YK series is well enhanced in PC3 image, medium enhanced information for WUL and ELL series in PC1 image; YK, WUL, EUL and ELL series are in PC2 image and UL series in PC3. It shows that most of the discernible soil units are picked up in PC1 and reverse in PC4 image.

Table-9 Differentiation of Soil Units and other Associated features on Principal Component Image using EASI / PACE Software.

S. No.	Soil Series & Associated Features	PC1	PC2	PC3	PC4
1	YK	Well En.	M. En.	Well En.	Sub.
2	TYK	Well En.	Well En.	Sub.	Sub.
3	UL	Sub.	Sub.	M. En.	Sub.
4	WUL	M. En.	M. En.	En.	Sub.
5	EUL	En.	M. En.	En.	Sub.
6	ELL	M. En.	M. En.	En.	Sub.
7	Geomorphic units	Sub.	Sub.	Well En.	Sub.
8	Biomass	Well En.	Sub.	Sub.	Sub.
9	Waterbodies	Well. En.	Well En.	Sub.	En.
10	Settlement	Well En.	M. En.	Sub.	Sub.

Well En. – Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. – Subdued.

The PC1, PC2, PC3 and PC4 have been generated and their statistical analysis in terms of covariance matrix, correlation coefficient matrix, eigon values, eigon vector and factor loading are given in tables 11 -to- 15.

Principle component analysis (PCA) has been performed on 512 × 512 image data. The mean covariance matrix, correlation matrix, eigon values, eigon vector and factor loading are shown in tables: 11 -to- 15.

Table-11 Covariance Matrix

CONVARIANCE MATRIX

LISS-II bands	1	2	3	4
1	17.7019	10.1593	9.0354	5.5228
2	10.1593	7.3016	6.7658	3.28780
3	9.0354	6.7658	7.4749	3.0181
4	5.5228	3.2878	3.0181	4.5264

Table-12 Correlation Matrix

CORRELATION MATRIX

LISS-II bands	1	2	3	4
1	1.000	0.8936	0.7853	0.6170
2	0.8936	1.000	0.9158	0.5719
3	0.7853	0.9158	1.000	0.5189
4	0.6170	0.5719	0.5189	1.000

Table-13 Eigon Values

EIGON VALUES

		Variance (%)	Cum. Variance (%)	Physical significance
PC4	31.4929	85.1048	85.1048	Brightness
PC3	02.8516	07.7060	92.8109	Greenness
PC2	02.2394	06.0515	98.8624	Δ Brightness
PC1	00.4210	01.1376	100.000	Δ Greenness

Table-14 Eigon Vector

EIGON VECTOR

SB \ PCA	PC4	PC3	PC2	PC1
4	0.2545	0.8015	-0.5411	0.0143
3	0.4364	-0.4965	-0.5439	-0.5170
2	0.4626	-0.2733	-0.1654	0.8270
1	0.7286	0.1910	0.6197	-0.2205

Table-15 Factor Loading

FACTOR LOADING

SB \ PCA	PC4	PC3	PC2	PC1
4	0.6712	0.6361	-0.3806	0.0044
3	0.8957	-0.3067	-0.2977	-0.1227
2	0.9607	-0.1708	-0.0916	0.1986
1	0.9718	0.0767	0.2204	-0.0340

6.6 Generation of FCCs from PC image

The enhancement techniques have been performed on digital image data to improve the interpretability of the digital image.

Initially statistical analyses were utilized to determine the amount and distribution of information content in all the four bands of IRS data. FCCs have been generated by three band combination g(x, y) image.

Table-10 represents the differentiation of soil units and other associated features on FCC image, generated from PC image.

The softwares, EASI / PACE and MGE respectively have been used for the generation of FCCs on 512 × 512 pixels image. These FCCs have explicited the different soil series (six) and other associated features, which are presented in plates 17 -to- 23.

In EASI / PACE software, the FCC images are PC4, PC3 and band 2 provide best discernibility for different soil series, followed by PC1, band 2 and PC4; PC3, band 1 and band 2, while poor discernibility on PC4, PC3 and band 1 image (Plates 17 -to- 20). It is clear from the FCCs that TYK and ELL soil series are well enhanced rather than other soil series. Among other associated features are geomorphic units is well enhanced followed by biomass, water bodies and settlement.

As the table-10 revealed that the MGE software provides low quality images as compared with image enhancement on EASI / PACE software. The FCCs generated on MGE software represents the grading of enhancement that can be seen in table-10 and their FCC images in plate 21 -to- 23. YK series is well enhanced in PC4, band 4 and PC3; band 4, PC3 and PC2 images, WUL series and other associated features by MGE software are generally represent low quality FCCs.

In the above comparative study of different soil series show that the most soil series are enhanced in EASI / PACE software with best quality images and their FCCs are presented in plates 17 -to- 23.

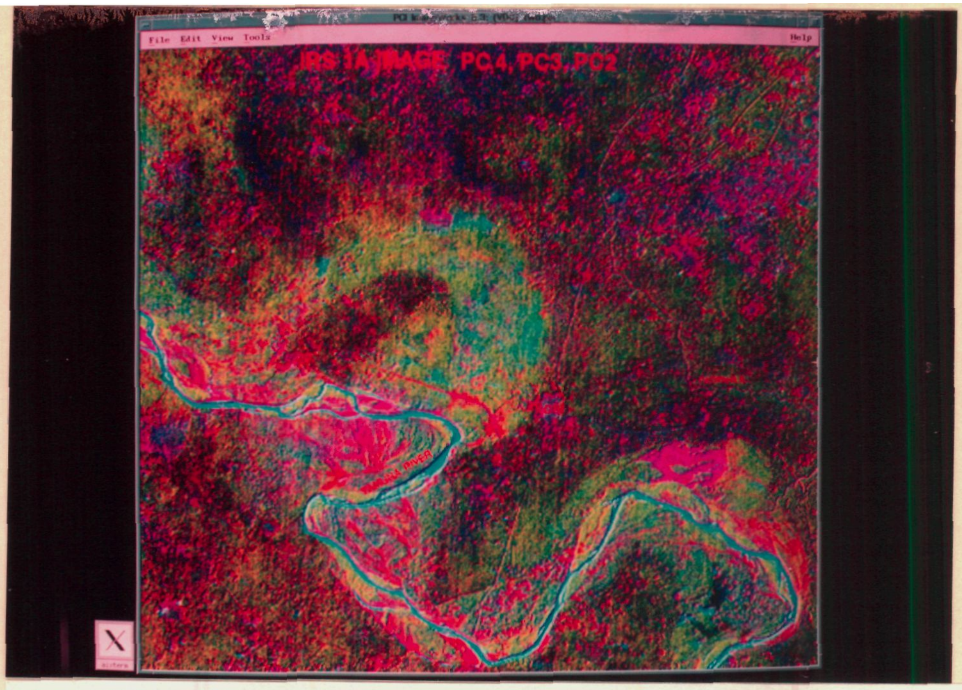


Plate-17 IRS-1A LISS II Image; PC_4, PC_3, PC_2 (Processed by V 5.3 EASI/PACE Software).

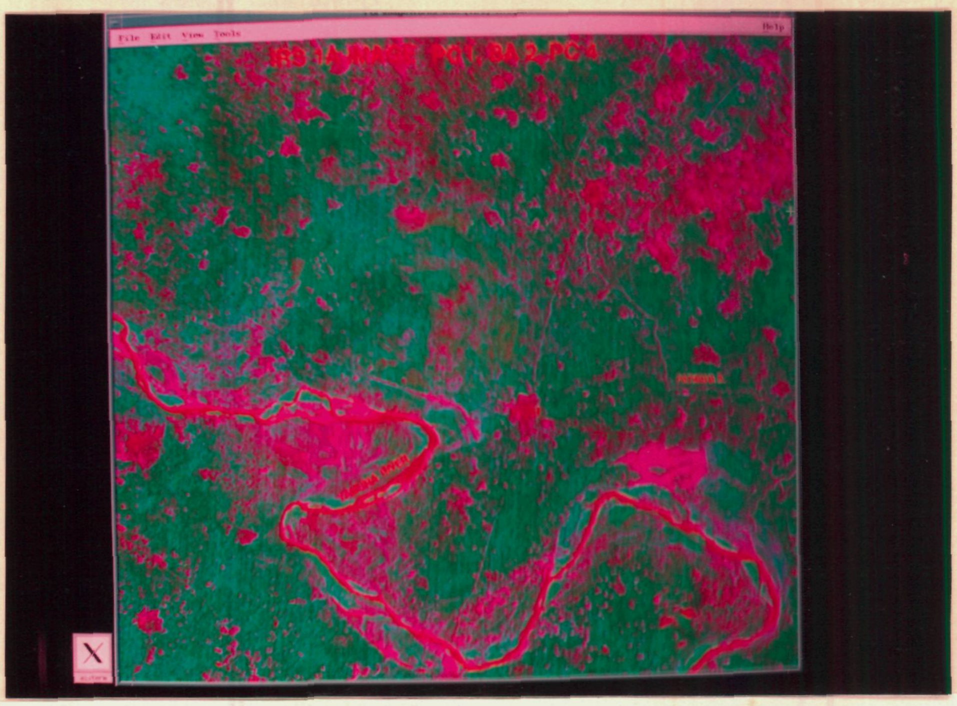


Plate-18 IRS-1A LISS II Image; PC_1, Band-2 and PC_4 (Processed by V 5.3 EASI/PACE Software).

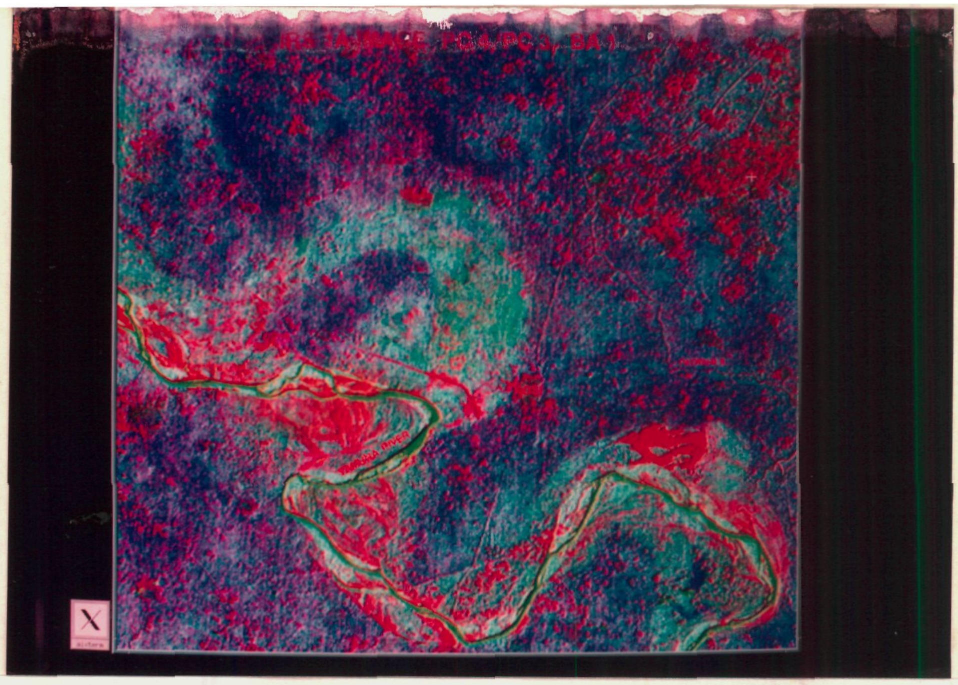


Plate-19 IRS-1A LISS II Image; PC_4, PC_3 and Band-1 (Processed by V 5.3 EASI/PACE Software).

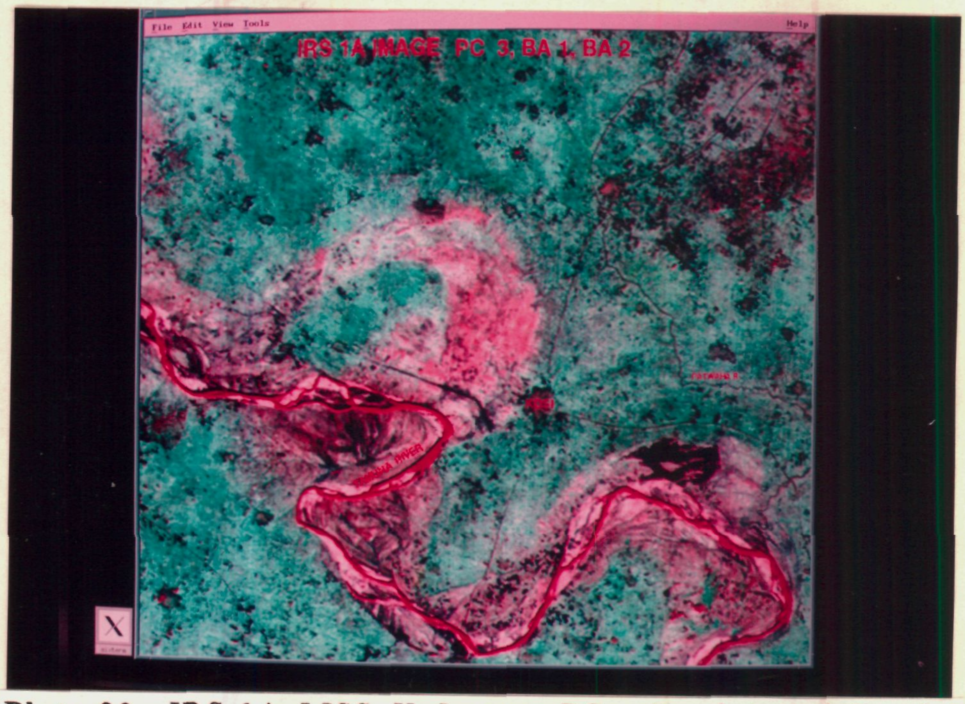


Plate-20 IRS-1A LISS II Image; PC_3, Band-1 and Band-2 (Processed by V 5.3 EASI/PACE Software).

TABLE-10 **Differentiation of Soil Units and other Associated features on FCCs**

S. No	Soil series & Associated Features	MGE Software			EASI / PACE Software			
		PC_4, B_4 & PC_3	B_4, PC_3 & PC_2	PC_4, B_3 & B_4	PC_4, PC_3 & B_2	PC_1, B_2 & PC_4	PC_4, PC_3 & B_1	PC_3, B_1 & B_2
1	YK	Well En.	Well En.	M. En.	M. En.	M. En.	Well En.	M. En.
2	TYK	M. En.	M. En.	Sub.	Well En.	Well En.	En.	Well En.
3	UL	Poorly En.	Poorly En.	Poorly En.	Sub.	M. En.	Sub.	Sub.
4	WUL	Sub.	Sub.	Sub.	M. En.	Sub.	Sub.	M. En.
5	EUL	Sub.	Sub.	Poorly En.	M. En.	Poorly En.	Poorly En.	Poorly En.
6	ELL	Sub.	Sub.	M. En.	Well En.	Well En.	En.	M. En.
7	Geomorphic unit	Sub.	Sub.	Sub.	Well En.	Sub.	Well En.	Well En.
8	Biomass	Sub.	Poorly En.	Poorly En.	En.	Well En.	Well En.	En.
9	Water bodies	Sub.	M. En.	Sub.	M. En.	Sub.	Sub.	M. En.
10	Settlement	Sub.	Sub.	Sub.	Poorly En.	M. En.	Poorly En.	En.

Well En. - Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. - Subdued

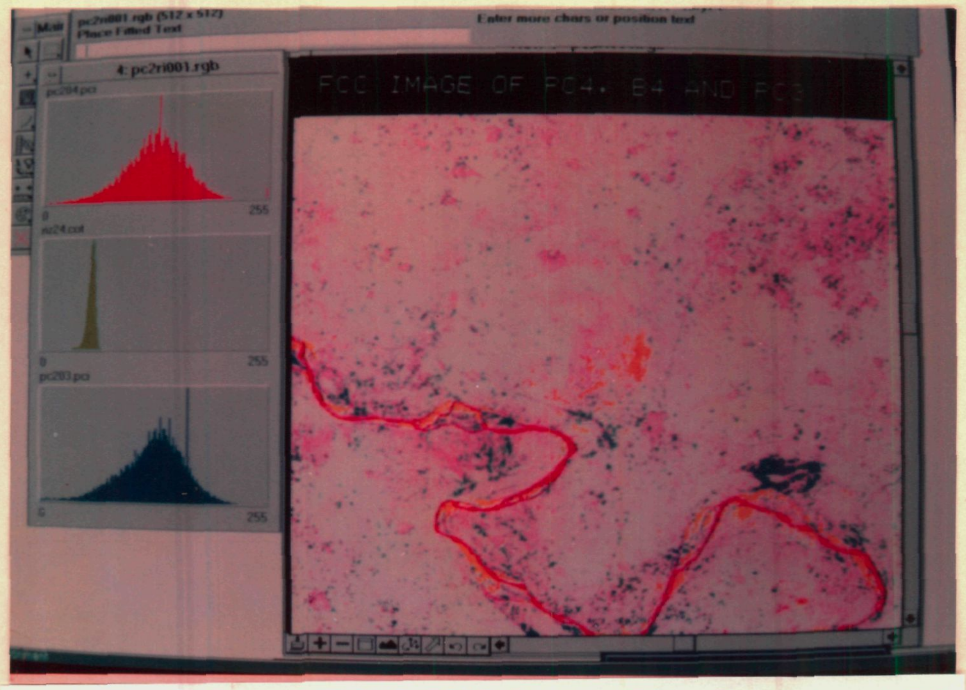


Plate-21 IRS-1A LISS II FCC Image; PC_4, Band-4 and PC_3 (Processed by 'MGE' Software).

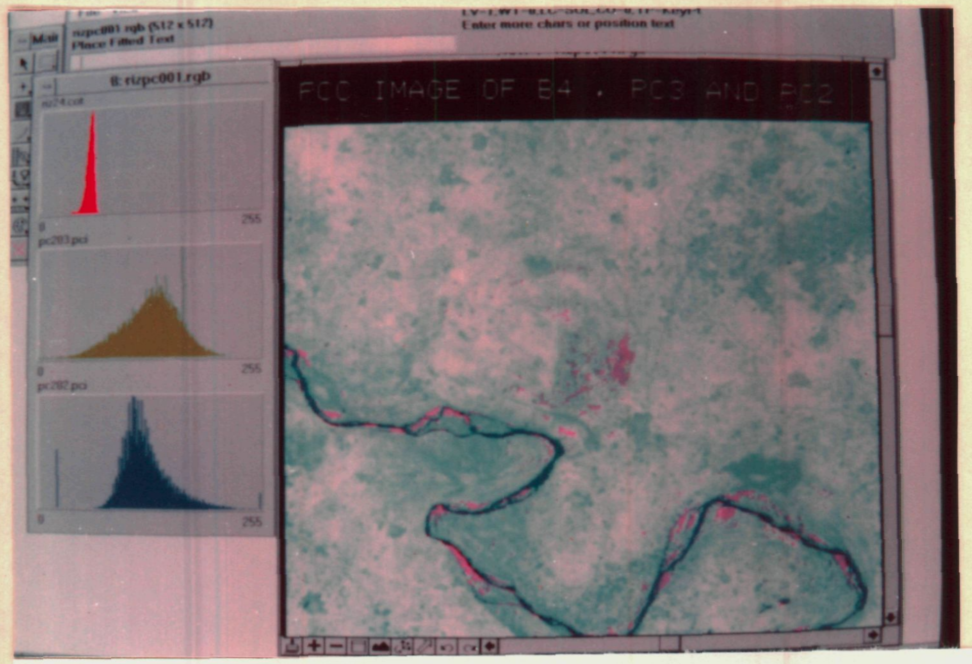


Plate-22 IRS-1A LISS II Image; Band-4, PC_3 and PC_2 (Processed by 'MGE' Software.

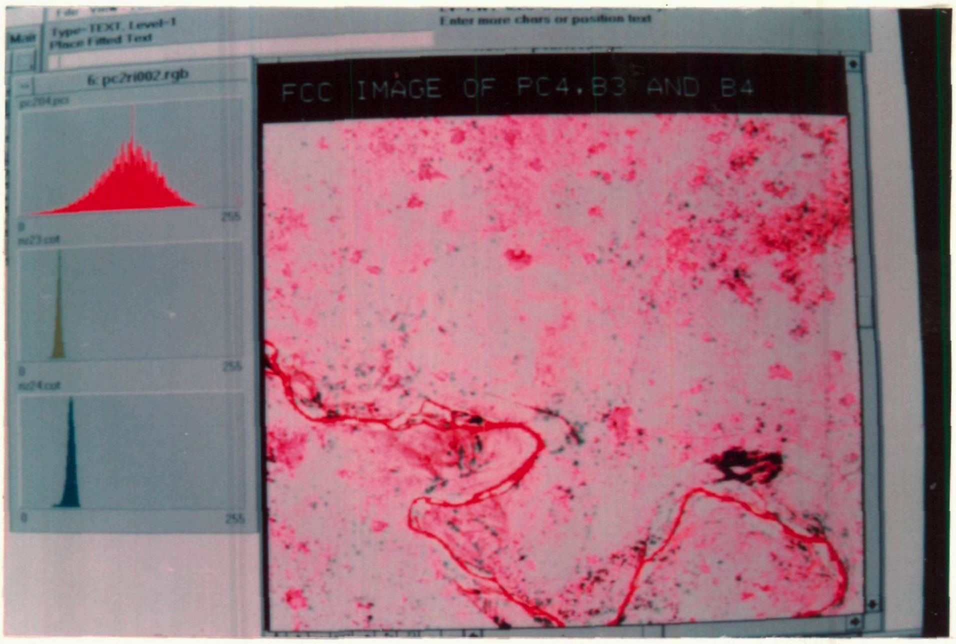


Plate-23 IRS-1A LISS II Image; PC_4, Band-3 and Band-2 (Processed by 'MGE' Software).

Medium enhanced soil series in FCC images and their band combination are; PC4, PC3 and band 2; PC1, band 2 and PC4; PC3 band 1 and band 2 (YK); PC1, band 2 and PC4 (UL); PC4, PC3 & band 2, and PC3, band 1 and band 2 (WUL); PC4, PC3 and band 2 (EUL); PC3, band 1 and band 2 (ELL) on EASI / PACE software, while PC4, band 3 and band 4 (YK); PC4, band 4 and PC3, and band 4, PC3 and PC2 (TYK); PC4, band 3 and band 4 (ELL) on MGE software respectively.

Medium enhanced for other associated features on FCC image and their band combination are PC4, PC3 and band 2, and PC3, band 1 and band 2 (water bodies); PC1, band 2 and band 4 (settlements) on EASI / PACE software, while band 4 PC3 and PC2 (water bodies) on MGE software.

UL soil series represents very less human influence, scattered vegetation cover and some places devoid of vegetation where high salinity and sodicity problems may exists; YK and TYK soil series are generally observed along the Yamuna river with very less or scattered seasonal vegetation, human influence is almost none except near the village, boundaries are gradational to clear and some places vague. These soil units are generally used for seasonal agricultural practice; WUL, EUL and ELL soil series are observed in the area away from the Yamuna river, these soil units are fertile in nature and commonly utilized agricultural practices.

6.7 Analysis of Filtered Images

Often, a filter- means of extracting a particular information (sub-set of data) from larger information (set) containing unwanted or irrelevant information.

In this section the filtering approach has been used to obtain better and clear information about spatial extent of soil types cover for optimum results.

The filters are: optical filter, digital filter and electrical filter. Earlier one passes only desired optical wavelengths of energy, while later

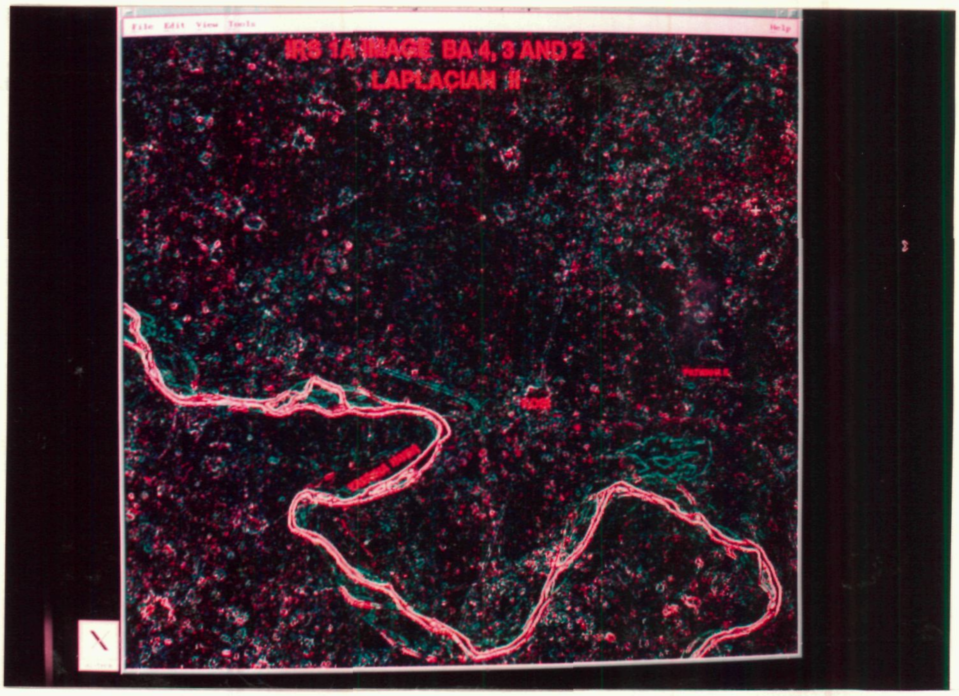


Plate-24 IRS-1A LISS II Image; Band-4, Band-3 and Band-2; Laplacian II (Processed by V 5.3 EASI/PACE Software).

are arithmetic procedure that operate on digital data stream in much the same way as an electrical filter operates on a continues electrical signal. (Gonzalez, *et al.*, 1987).

In present study, the filters have been used viz. Laplacian-II - histogram linear enhancement, Prewitt-equal enhancement, Edge sharpening-equal enhancement, low-pass (L. P.), high pass (H. P.) and Gaussian filters.

The above filters have been used for smoothing, sharpening and for edge detection of images containing various spectral information, and enhanced soil seperability class.

Table-16 illustrates the differentiation of soil units and other associated features on filtered images.

Image processing have been carried out using two softwares namely: EASI /PACE and MGE software for the generation enhanced filtered images. Grading of enhancement for identification of different soil series and other associated features are given in table-16.

The product of filtered images by MGE software is presented in plates 27 -to- 29, and by EASI / PACE software is presented in plates 24 -to- 26.

The above table has explicited six soil series, which can be seen in the extracted 512 × 512 pixels image. The filtered images represent best information regarding soil series and associated features on EASI / PACE software as compared to the MGE software.

In EASI / PACE software, the filtered images are Laplician-II, Edge sharpening and Prewitt filtered. Among these filtered images, Edge sharpening image provides best enhancement for UL and WUL soil series, for biomass and settlement as associated features; followed by Prewitt filtered and Laplician-II filtered images provide in term of poor enhancement for differentiation of soil series, geomorphic units, water bodies has associated features.

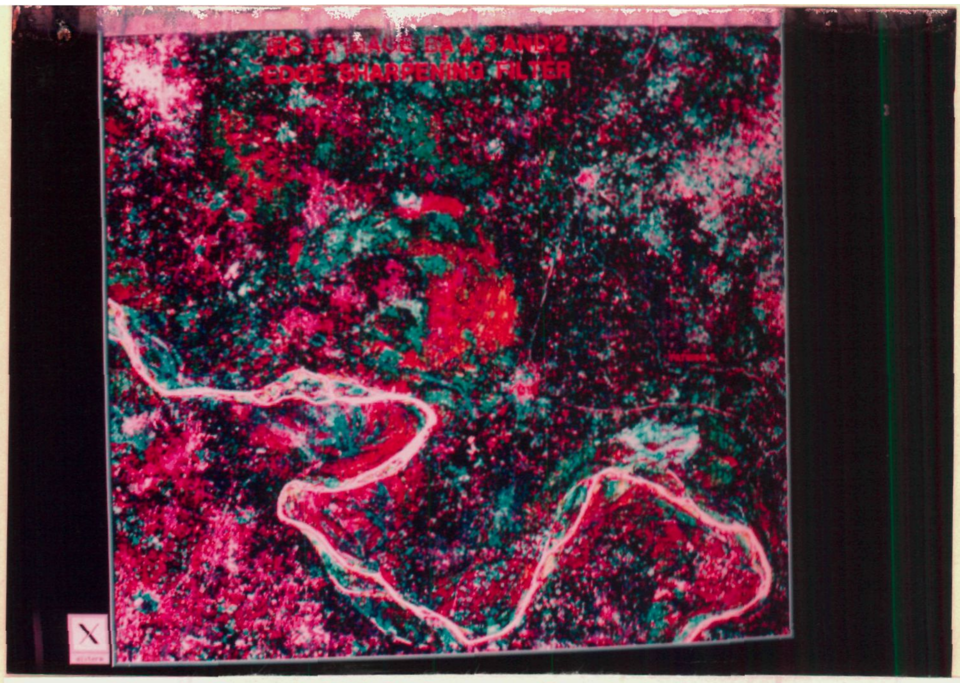


Plate-25 IRS-1A LISS II Image; Band-4, Band-3, and Band-2; Edge Sharpening Filter (Processed by V5.3 EASI/PACE Software).

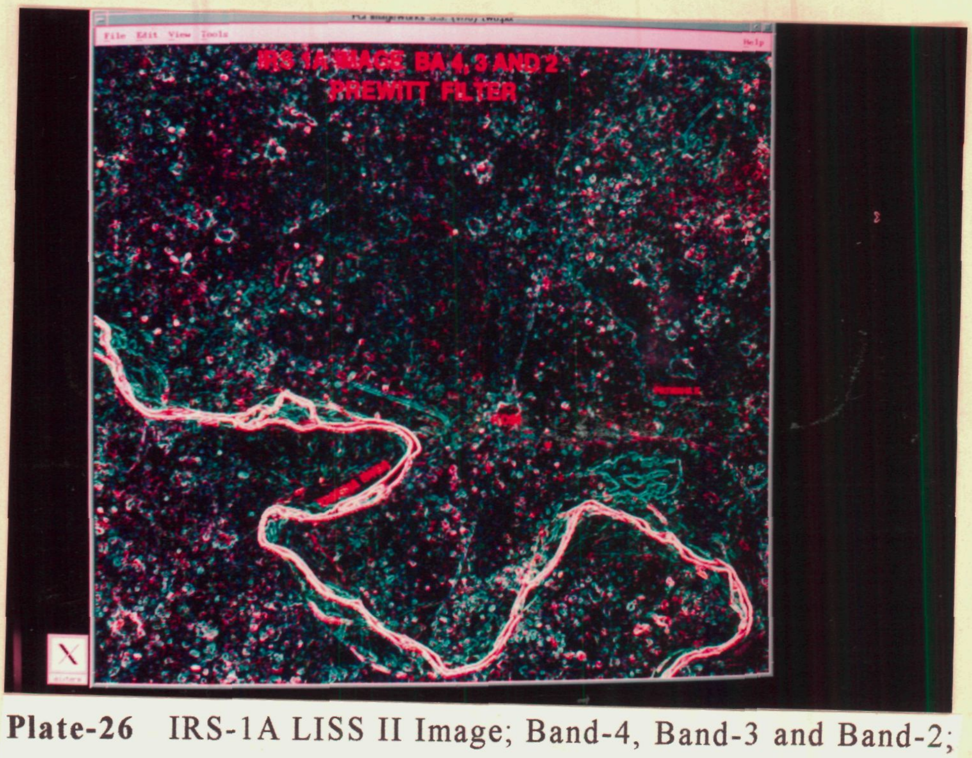


Plate-26 IRS-1A LISS II Image; Band-4, Band-3 and Band-2; Prewitt Filter (Processed by V 5.3 EASI/PACE Software).

TABLE-16 **Differentiation of Soil Units and other Associated features on Filtered Images**

S. No	Soil series & Associated Features	EASI / PACE Software			MGE Software		
		Laplacian-II	Edge Sharpning	Priwitt	High Pass	Low Pass	Gaussian
1	YK	Poorly En.	Sub.	Sub.	Poorly En.	M. En.	Poorly En.
2	TYK	Sub.	Poorly En.	Poorly En.	Poorly En.	M. En.	Well En.
3	UL	Sub.	Well En.	Sub.	Sub.	M. En.	En.
4	WUL	Sub.	Well En.	Poorly En.	Sub.	M. En.	M. En.
5	EUL	Sub.	M. En.	Poorly En.	Sub.	Sub.	Poorly En.
6	ELL	Sub.	M. En.	Sub.	M. En.	M. En.	Sub.
7	Geomorphic unit	Sub.	Poorly En.	Sub.	Poorly En.	M. En.	Poorly En.
8	Biomass	Poorly En.	M. En.	Sub.	Sub.	Sub.	En.
9	Water bodies	Sub.	Sub.	Sub.	Sub.	En.	M. En.
10	Settlement	En.	M. En.	M. En.	M. En.	Sub.	M. En.

Well En. – Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. - Subdued

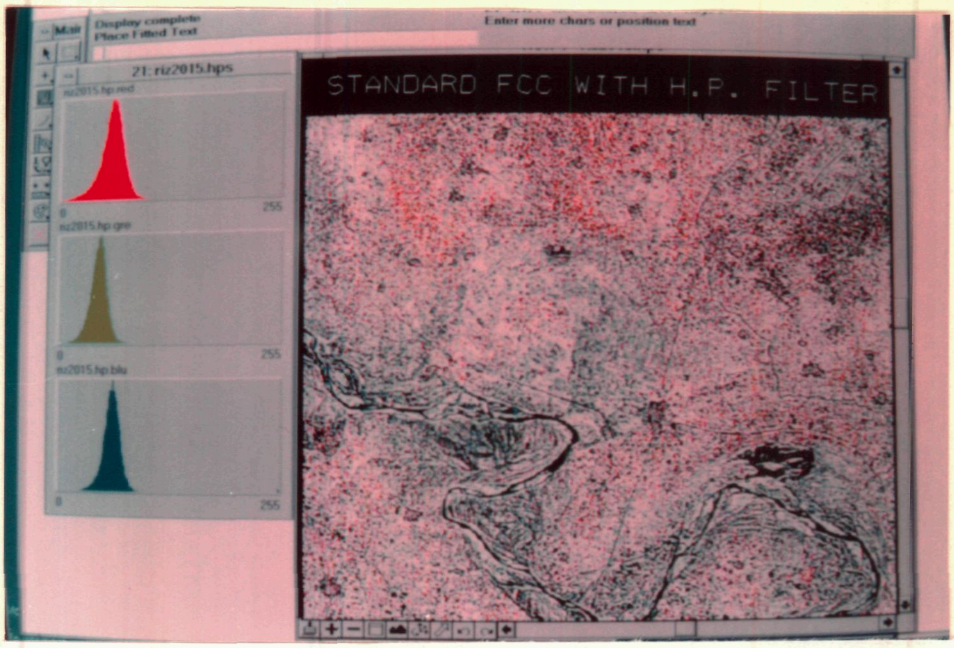


Plate-27 IRS-1A LISS II Image; Band-1, Band-2 and Band-3; High Pass Filter (Processed by 'MGE' Software).

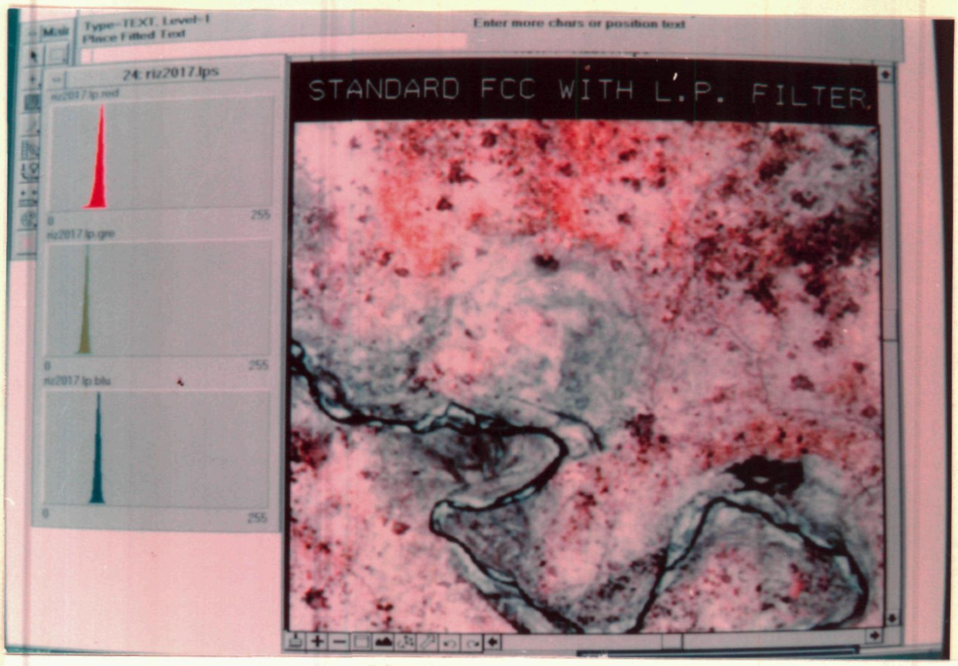


Plate-28 IRS-1A LISS II Image; Band-1, Band-2 and Band-3; Low Pass Filter (Processed by 'MGE' Software).

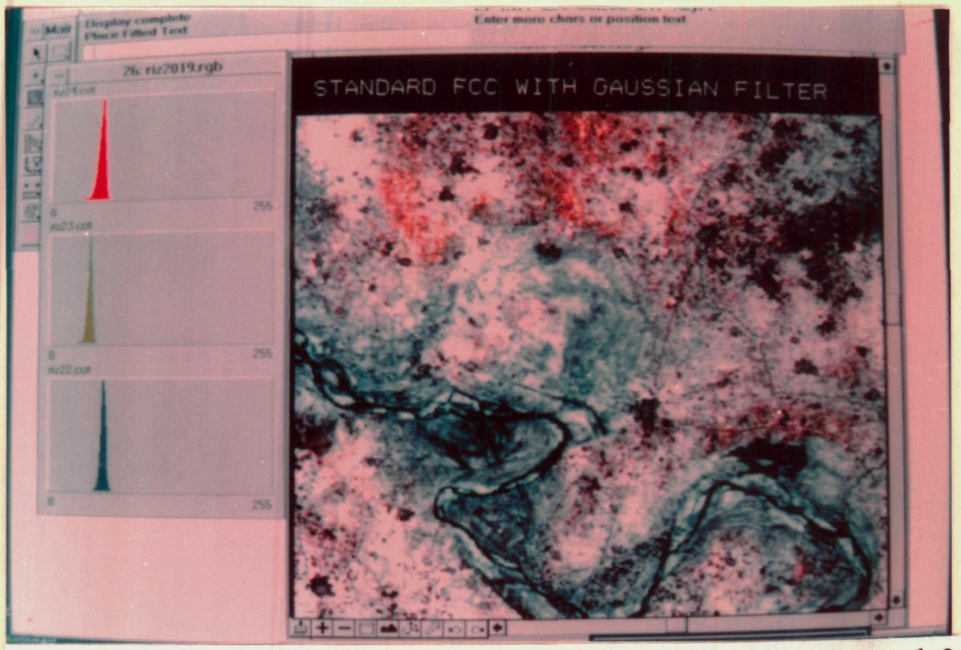


Plate-29 IRS-1A LISS II Image; Band-1, Band-2 and Band-3; Gaussian Filter (Processed by 'MGE' Software).

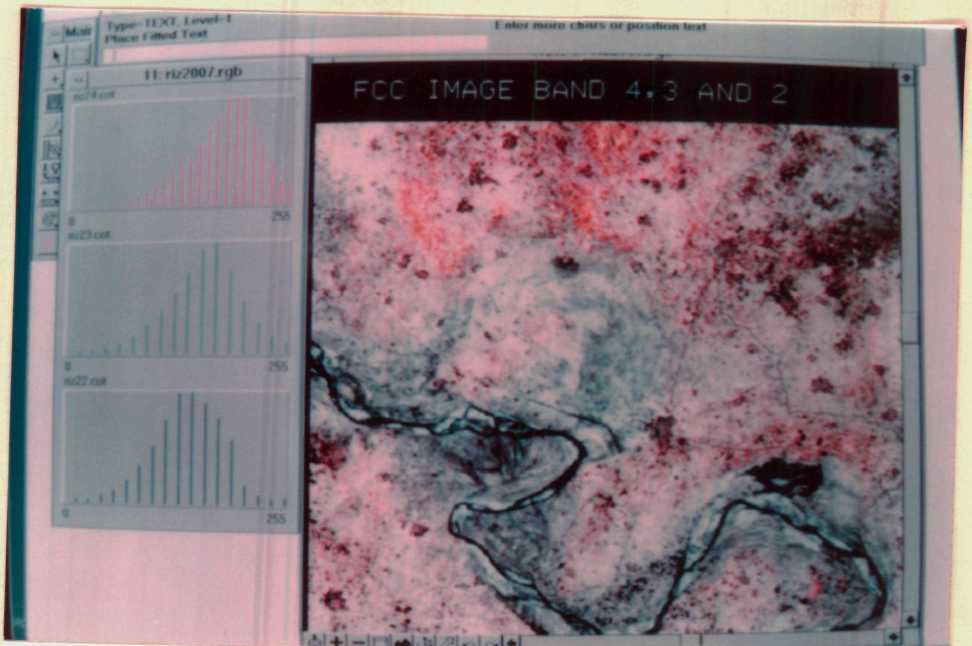


Plate-30 IRS-1A LISS II FCC Image; Band-4, Band-3 and Band-2 (Processed by 'MGE' Software).

Medium enhanced in edge sharpening filtered image are EUL, ELL; biomass and settlement; in Prewitt filtered image is settlement, while remaining soil series and associated features are generally represent poor enhancement on Laplician-II and Prewitt filtered images, which can be seen table-16.

In MGE software, the filtered images are high pass, low pass and Gaussian (mean: 131 and S.D. 57). The image has generated through these filters are presented in plates 29 -to- 31. Among these filtered images, low pass filtered image show moderate enhancement for YK, TYK, UL, WUL, ELL soil series and geomorphic units (point bars, channel bars and meander scar) and hence may be treated as best enhancement. In high pass filtered image, ELL and settlement are enhanced. In Gaussian filtered, TYK, WUL soil series, water bodies and settlements are enhanced.

The above information about six soil series are discriminated by visual analysis of filtered images and their interpretation are presented in table-16.

In general, low pass filter image represents blurred appearance in term of quality, while high pass filtered image shows grainy or grassy appearance on filtered images on MGE software (Plates: 27 & 28). Laplician-II and Prewitt filtered images revealed linear and circular edges on EASI / PACE software.

6.8 Interpretation of IHS and FCCs Images

The digital interpretation of various FCCs have been carried out for this study, in which FCCs were generated by assigning new values in terms of primary colours i.e. RGB. Plates: 33 -to- 39 showing combination of three bands from visible and infrared regions. In these FCCs, three bands are assigned to red, green and blue tristimulus values of the multi-spectra LISS II data as a function of (Fi) as:

$$\left.\begin{aligned} R_D &= \phi R(F_1, F_2, \ldots\ldots\ldots\ldots) \\ G_D &= \phi R(F_1, F_2, \ldots\ldots\ldots\ldots) \\ B_D &= \phi R(F_1, F_2, \ldots\ldots\ldots\ldots) \end{aligned}\right\} \quad \ldots\ldots(i)$$

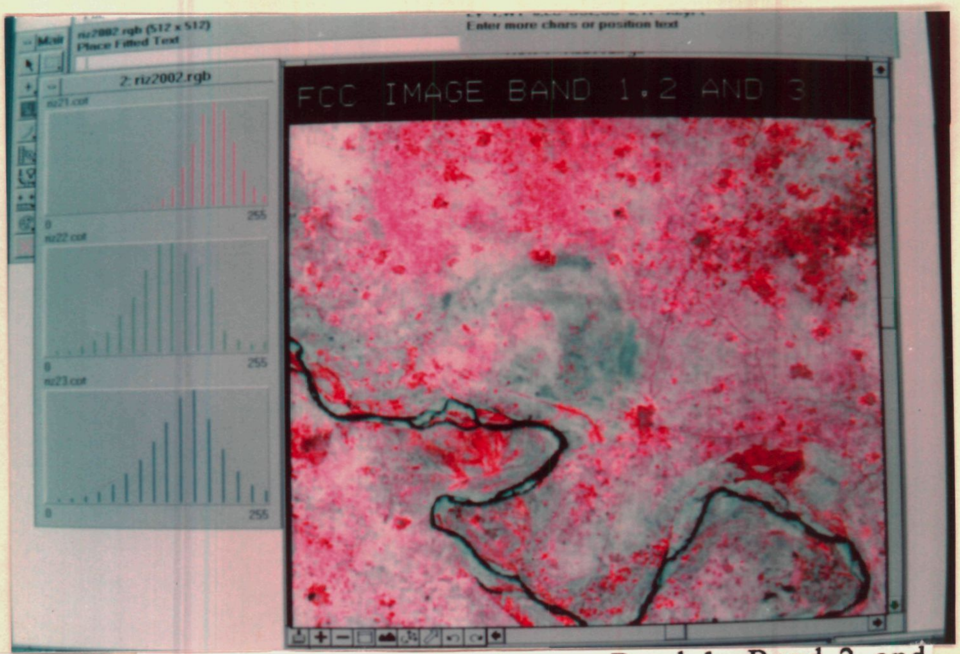


Plate-31 IRS-1A LISS II; FCC Image; Band-1, Band-2 and Band-3 (Processed by 'MGE' Software).

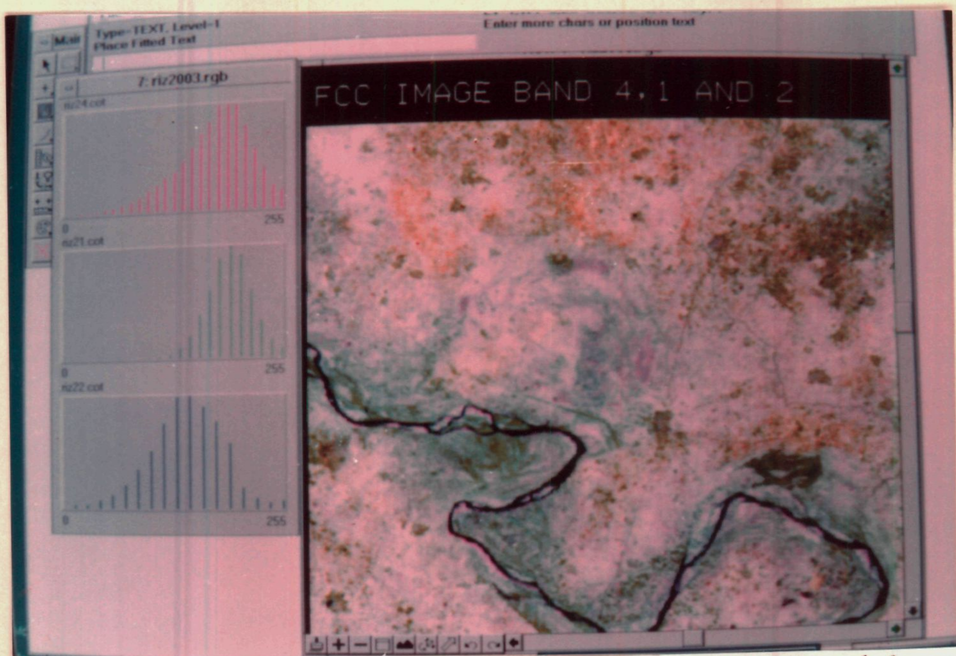


Plate-32 IRS-1A LISS II; FCC Image; Band-4, Band-1 and Band-2 (Processed by 'MGE' Software).

where, ϕ R (.), ϕ G (.) and ϕ B (.) are general functional operations. These sets of RGB i.e. red, green and blue region are tristimulus values ($Rs = F_1$, $Gs = F_2$, $Bs = F_3$) can be interchanged according to the relation (ii), where R_D, G_D and B_D are the new colour values of the DN in the FCC images.

$$\begin{bmatrix} R_D \\ G_D \\ B_D \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} \quad \text{.......(ii)}$$

By keeping this operation FCC, the original green objects become red, blue objects appear green and red objects appear blue in the standard FCC (Plate-35), while the original FCC can be seen in plate-37.

Spatial distribution and changes in soil cover with combination of RGB through FCC techniques have been processed. This technique offer an efficient means for combing wavelengths for discrimination of soils, whereas two spectrally different soil areas are nearly indistinguishable in single band image. The proper combination of different bands data permits discrimination on the basis of colours difference.

Table-17 explicit the differentiation of soil units and other associated features on FCCs image data.

Two softwares were used for generation of enhanced FCCs images. The FCCs are B1, B2 & B3; B4, B3 & B2; B2, B4 & B1; B2, B3 & B4; B4, B1 and B2 on MGE software are presented in plates 30 -to- 34, while on EASI / PACE software, the FCCs are B4, B3 & B2; B1, B2 & B3; B1, B4 & B3 are generated and their images are presented in plates 35 -to- 37.

From the table it is clear that appearance of soil series on FCCs images are better quality image in EASI / PACE software as compared to MGE software.

The above FCCs are generated on both the softwares and extracted 512 × 512 images for the seperability class of different soil units.

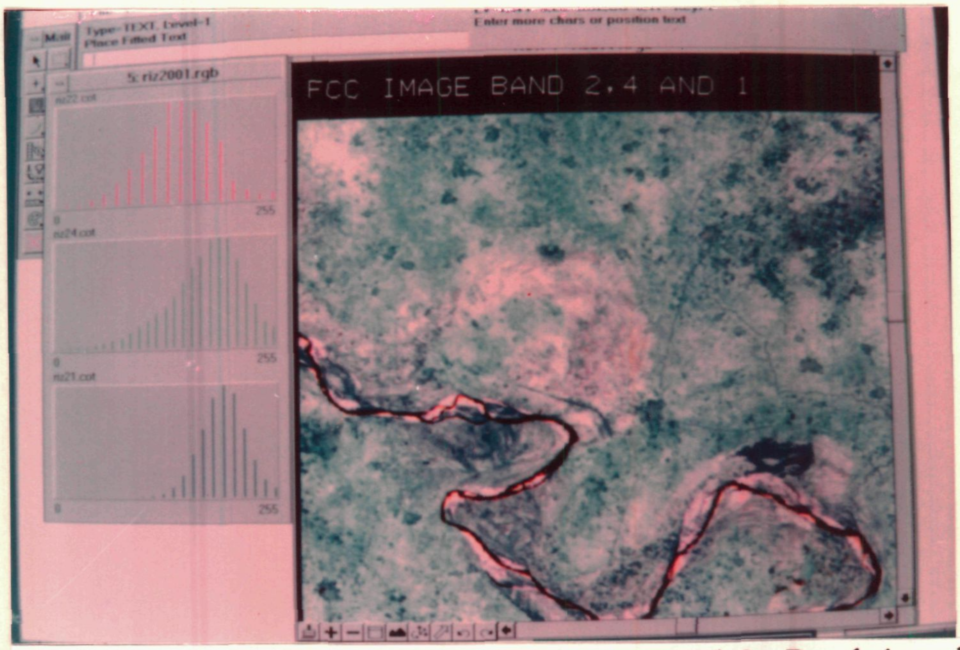


Plate-33 IRS-1A LISS II; FCC Image; Band-2, Band-4 and Band-1 (Processed by 'MGE' Software).

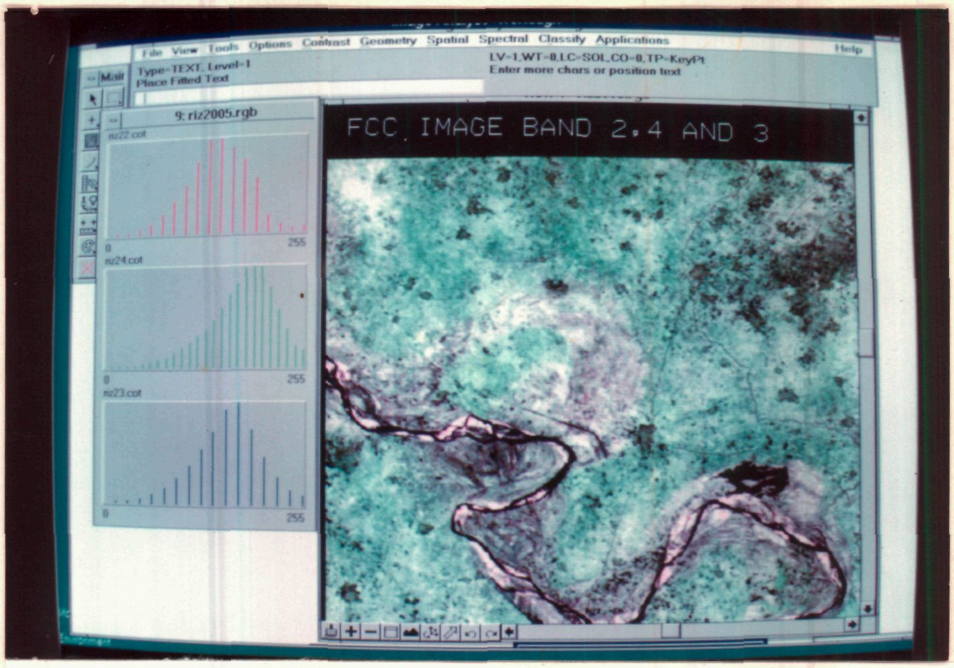


Plate-34 IRS-1A LISS II; FCC Image; Band-2, Band-3 and Band-4 (Processed by 'MGE' Software).

TABLE-17 Differentiation of Soil Units and other Associated features on FCCs.

S. No	Soil series & Associated Features	MGE Software				EASI / PACE Software		
		B:4, 1 & 2	B:4, 3 & 2	B:2, 4 & 1	B:2, 3 & 4	B:4, 3 & 2	B:1, 2 & 3	B:1, 4 & 3
1	YK	Well En.	Sub.	M. En.	Well En.	En.	Well En.	M. En.
2	TYK	Sub.	En.	Sub.	Sub.	M. En.	Well En.	En.
3	UL	En.	M. En.	Sub.	Sub.	En.	En.	En.
4	WUL	Sub.	En.	M. En.	Sub.	Well En.	M. En.	Well En.
5	EUL	Sub.	M. En.	M. En.	M. En.	Sub.	Sub.	Sub.
6	ELL	En.	Sub.	En.	En.	En.	En.	M. En.
7	Geomorphic unit	Well En.	M. En.	M. En.	M. En.	Well En.	Well En.	Well En.
8	Biomass	Well En.	Well En.	En.	En.	Well. En.	Well En.	Well En.
9	Water bodies	Well En.	Well En.	En.	Sub.	Well. En.	M. En.	En.
10	Settlement	Sub.	Poorly En.	Sub.	Sub.	En.	En.	En.

Well En. – Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. - Subdued

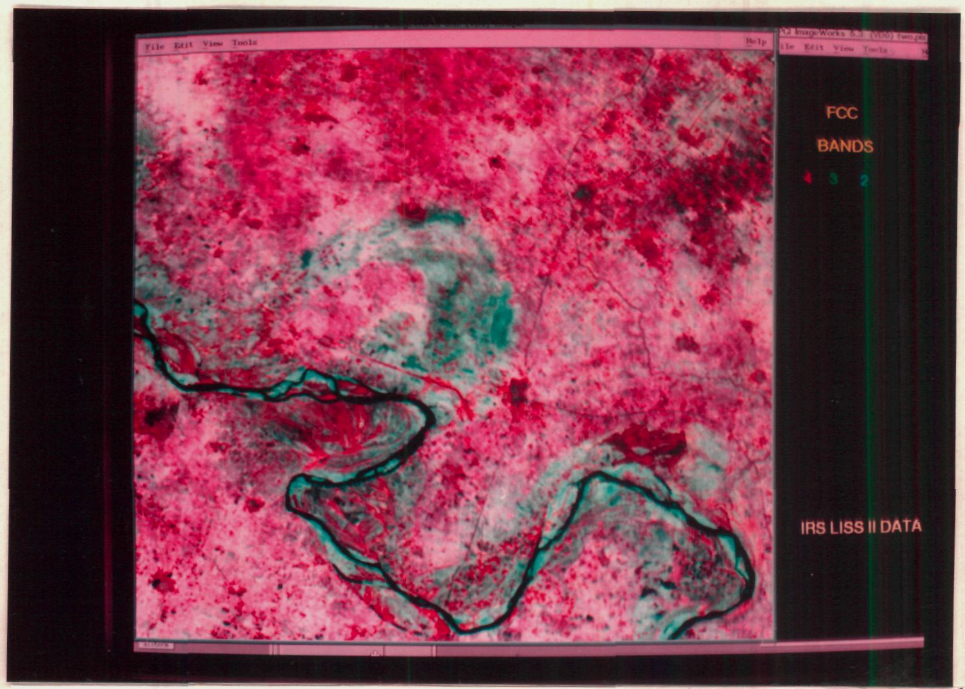


Plate-35 IRS-1A LISS II; Standard FCC, Band-4, Band-3 and Band-2, Image (Processed by V 5.3 EASI/PACE Software).

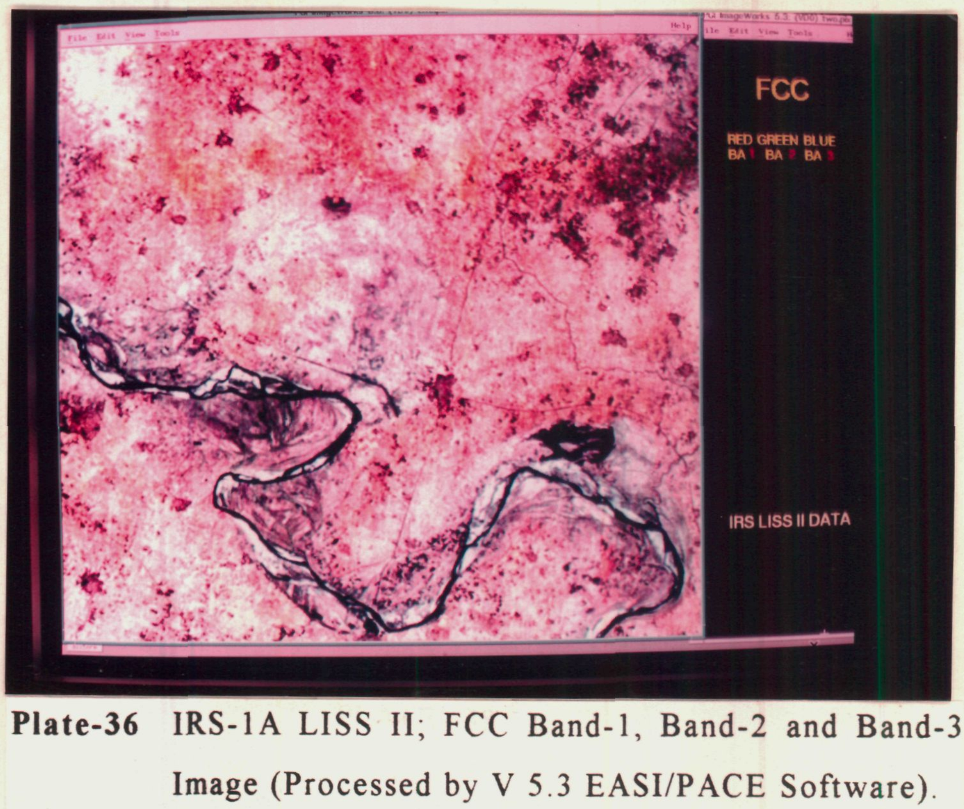


Plate-36 IRS-1A LISS II; FCC Band-1, Band-2 and Band-3 Image (Processed by V 5.3 EASI/PACE Software).

In the EASI / PACE software, the FCCS images B1, B2 & B3 (FCC) provide better enhancement for different soil series, followed by B1, B4 & B3; B4, B3 & B2, while the biomass and geomorphic features, water bodies are well enhanced on B4, B3 & B2 image.

However, in MGE software, the FCC images are provides different soil series with RGB variation. Well enhancement soil series is TYK on B4, B1 & B2; B2, B3 & B4 combination of bands, while medium enhanced FCCs are B2, B4 & B1 (YK, WUL & EUL); B4, B3 & B2 (UL & EUL); B2, B3 & B4 (EUL).

YK & TYK soil series are continuous change in shape and size with migration of river in different time and season, their exact areal extent can not be ascertained during the data acquired. The soil series on FCC represent very high spectral variability, the soils, which periodically undergoes submergence during high flood levels. The other associated features viz., point bar and channel bars and it is characterized by development of meander scars and cut of meanders, water bodies and vegetation cover are visually identified on FCCs.

Table-18 shows the differentiation of soil units and other associated features on Intensity, Saturation, Hue, and IHS Transformation using EASI / PACE software.

EASI / PACE software was used for the generation of IHS and IHS transformation images for the enhancement of six soil series and other associated features. These images are presented in plates 30 –to- 41, and their grading in terms of well enhancement, medium enhancement, enhancement, poor enhancement and subdued are given in table-18.
From the table, it is explicited that out of the six soil series that are analyzed in the extracted 512 × 512 images for different soil series are discernable on hue image followed by Intensity image. Saturation and IHS Transformation may be termed as poor for different soil units.

It is thus, clear from the table-18 that most of the thematic discernable information are best picked up in Intensity, Hue and IHS

Plate-37 IRS-1A LISS II; FCC, Band-1, Band-4 and Band-3 (Processed by V 5.3 EASI/PACE Software).

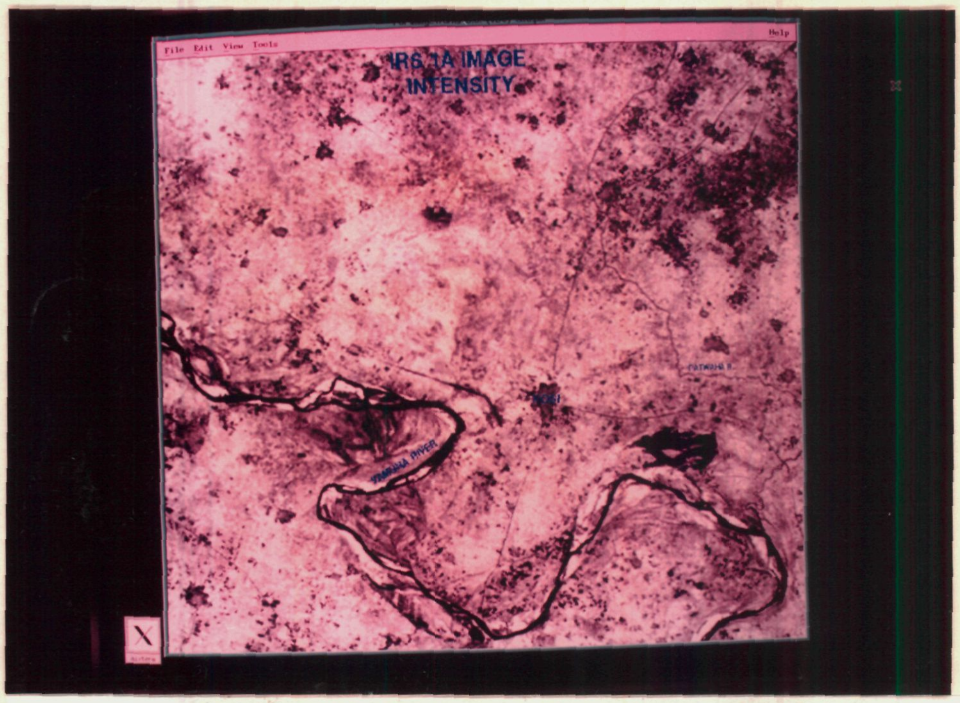


Plate-38 IRS-1A LISS II Image; Intensity Image (Processed by V 5.3 EASI/PACE Software).

Transformation. Poor thematic information is observed in Saturation image. These thematic discernable information can be seen in plates 38 -to-41, which indicated the separable soil units and other associated features on IHS images.

Intensity image provide best enhanced for different soil series, followed by Hue, IHS Transformation and Saturation.

Among various associated features on the images are well discernable on IHS Transformation image followed by Hue, intensity and Saturation images.

Geomorphic units (meander scar, point bar, and channel bar) is well enhanced on Hue and IHS Transformation; biomass (crop, vegetation and forest cover) is well enhanced on IHS Transformation; and settlements are well enhanced on Intensity and Hue images and moderately enhanced in IHS Transformation image.

The above interpretation revealed that the soil series are well discernable by using IH and IHS Transformation image processing techniques on EASI / PACE software except Saturation image.

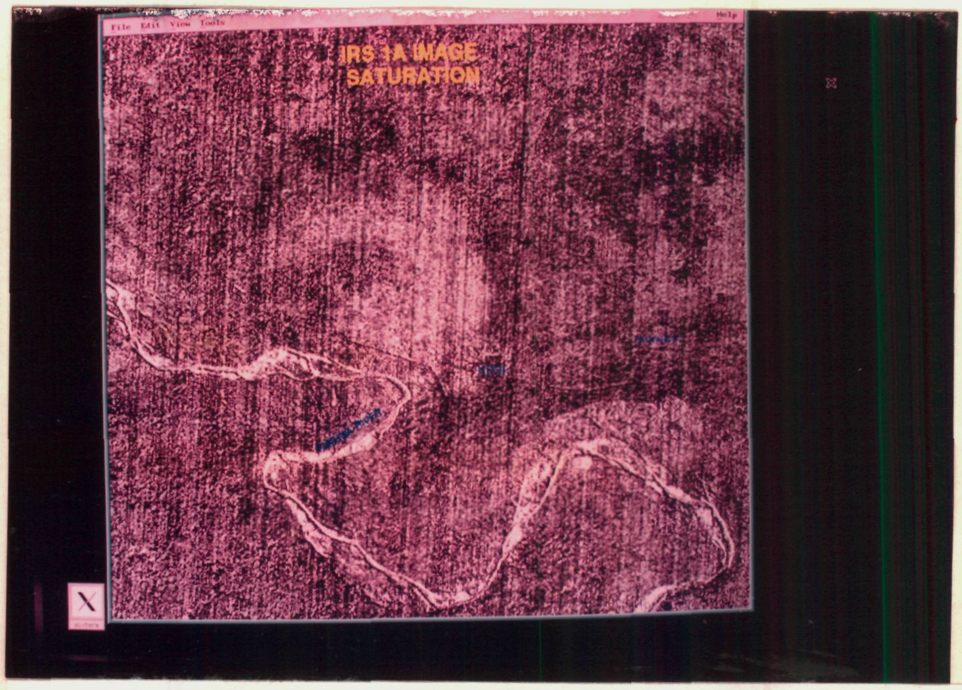


Plate-39 IRS-1A LISS II Image; Saturation Image (Processed by V 5.3 EASI/PACE Software).

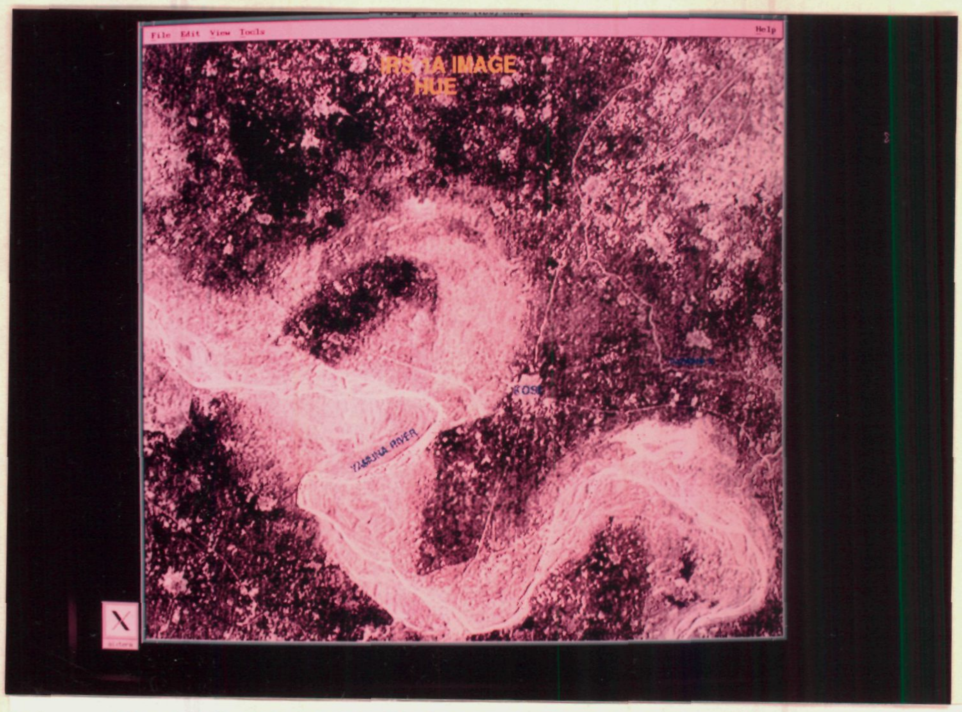


Plate-40 IRS-1A LISS II Image; Hue Image (Processed by V 5.3 EASI/PACE Software).

Table-18 Differentiation of Soil Units and Other Associated features on Intensity, Saturation, Hue and IHS Transformation Images using EASI / PACE Software.

S. No.	Soil series & Associated features	Intensity	Saturation	HUE	HIS Transforma -tion
1	YK	M. En.	Well En.	Sub.	Well En.
2	TYK	M. En.	Sub.	Well En.	En.
3	UL	En.	Sub.	M. En.	Sub.
4	WUL	M. En.	Sub.	En.	En.
5	EUL	M. En.	Sub.	M. En.	Sub.
6	ELL	En.	Sub.	En.	En.
7	Geomorphic units	Sub.	Sub.	Well En.	Well En.
8	Biomass	En.	Sub.	M. En.	Well En.
9	Water bodies	M. En.	Poorly En.	Sub.	Well En.
10	Settlements	Well En.	Sub.	Well En.	M. En.

Well En. – Well Enhanced; M. En. – Moderately Enhanced; En. – Enhanced; Poorly En. – Poorly Enhanced; Sub. – Subdued.

6.9 Automated Classification

The classification of soils and their associated objects have been carried out for soil classes through classification techniques in which pixels are classified during processing and the soil classes are defined according to the statistical properties of data or according to the analysis of spectral signature in training set (Mulders, 1987). Ali (1993) has developed new statistical methods for analyzing non-normal remotely sensed data. These methods have increased the accuracy of classification of an image and consequently made the use of remotely sensed more dependable.

Sabins (1978) has distinguished two type of classifications, the supervised and the unsupervised classifications both these classification techniques have been used in the present study.

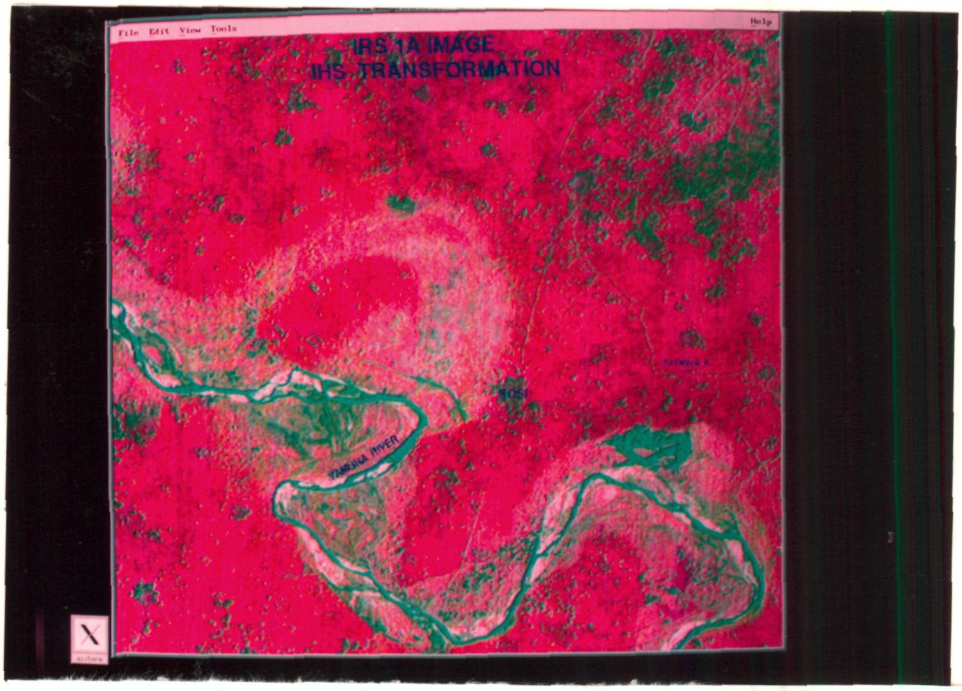


Plate-41 IRS-1A LISS II Image; IHS Transformation Image (Processed by V 5.3 EASI/PACE Software).

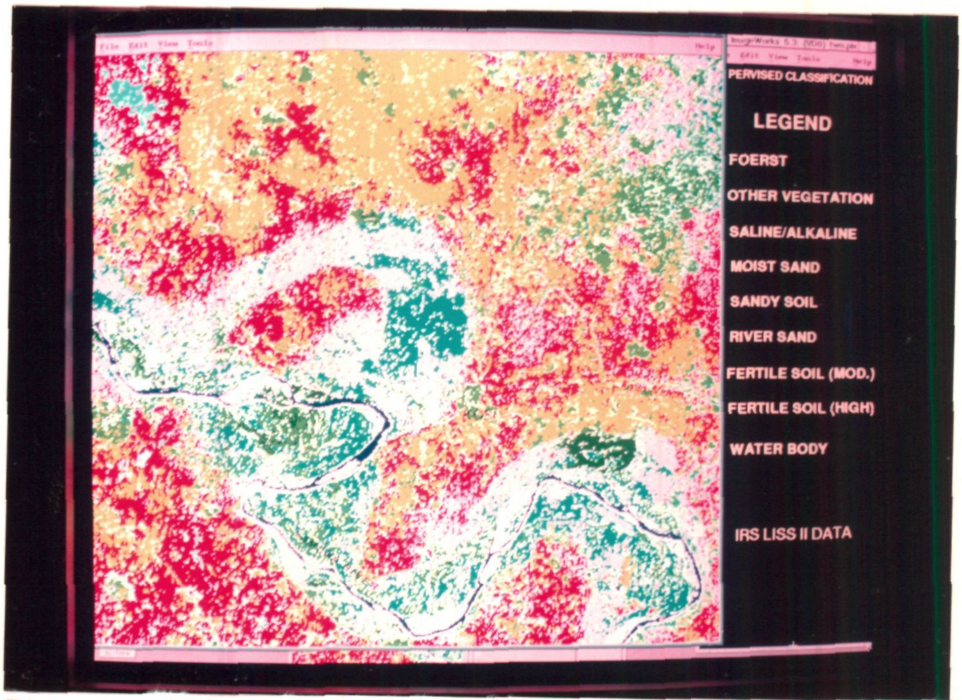


Plate-42 IRS-1A LISS II Image; Supervised Classification Image (Processed by V 5.3 EASI/PACE Software).

The aim of the digital image classification procedure is to automatically categories all pixels present in a image (Plates: 42 and 43) to soil class depending upon the gray levels scale.

6.9.1 Unsupervised Classification

The approach of this classification is to determine spectrally separable classes and then define their information utility. The image data are first classified by aggregating them into the natural spectral clusters present in 512 × 512 image (Plate-43) then the image is interpreted/analyzed for the extraction of different themes to know the separability of soils.

The spectral pattern present within the image (Plate-43), each pixel is used for categorization through the computer intelligency. After the computer decision, the different soil categories manifest different combination of DN values based on their inherent spectral reflectance and emittance properties. Each pixel in the image is then compared to each category by their hue during interpretation. Plate-43 illustrates the spectrally separable classes.

Using EASI / PACE software, and Unsupervised classification technique has been performed for the identification of different soil series on the image.

Eight clusters were assigned to class the various soil units on 512 × 512 image (plate-43).

Red and grayish-red colour explicit the UL soil series; cyan colour YK soil series; magenta and purple colour TYK soil series; yellow and green colour WUL, EUL and ELL soil series; white colour vegetation cover and settlements; cyan colour and isolated patch forest and blue colour water bodies.

Among the above soil series, ELL, EUL and WUL represent spectrally unseparable class, while UL soil series is easily identified for the categorization into two units viz., high salt-affected soil with high salt

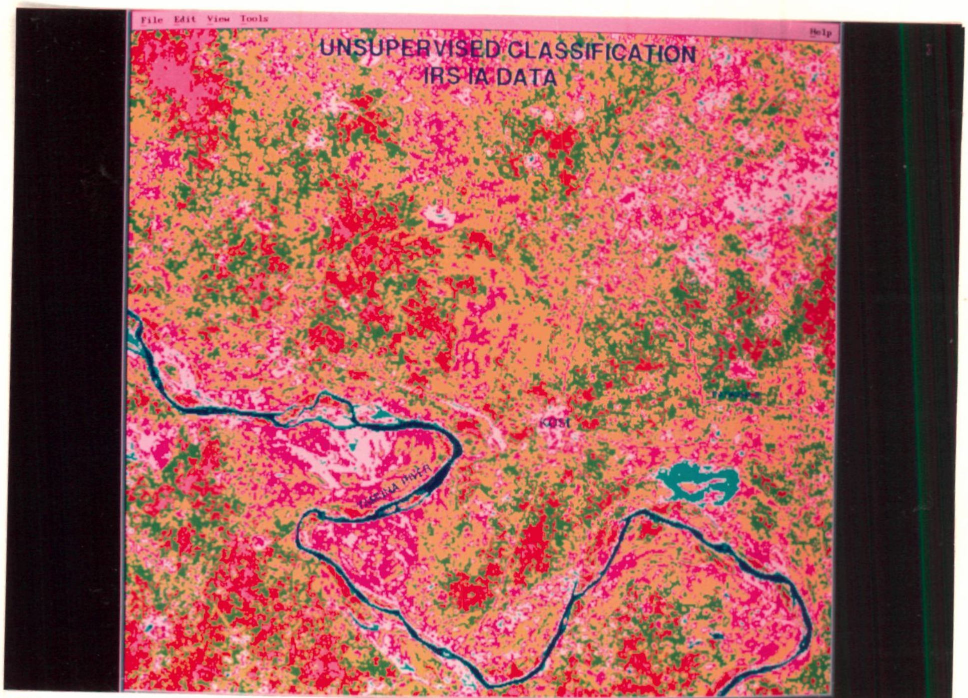


Plate-43 IRS-1A LISS II Image; Unsupervised Classification Image (Processed by V 5.3 EASI/PACE Software).

concentration, surrounded by low salt concentrated soil by their grayish red colour respectively.

Thus, it is clear that for soil classification in an area like Mathura District, Unsupervised classification does not provide spectrally separable class probably due to the influence of crop cover and intermixing of spectral signatures of different soil classes as is evident on the unsupervised classification output.

6.9.2 Supervised Classification

In this automated technique, the training classes are defined for classification of the spectral data statistically. In this process, the spectral patterns in the image data set are evaluated in the computer using predefined decision rules to determine the identity of each pixel. Maximum likelihood classification is done to statistically separate the different classes based on the statistics.

The statistics of the supervised classification are presented in table-15. Statistically, better separation of soils and associated features with number of pixel, per cent in image cover and per cent area in meters are given in table-15 and comparisons of ground observation data with supervised classification revealed that spectral pattern of UL, YK and TYK soil series are very much enhanced with bright tone, and high reflectance, the pattern and identification of other soils are ELL and WLL soil series were also depicted by colours, pattern and associations. The yellow colour of ELL and WLL soil series is on account of high organic matter content, medium to fine grain size distribution. Spectral response for classes TYK and YK are almost same in spectral behaviours except UL soil series. These soil series are exhibited by excellent spectral separability than ELL and WLL soils series respectively. The magnitude of spectral reflectance for series UL is different from the series, YK and TYK by their geomorphic position, pattern, their association and finally their physico-chemical characteristics. Of the 262744 pixels, 36905 pixels having null information in 512 × 512 image due to distortion of either one strip of data or some other reasons.

Unsupervised classification technique has been performed on EASI / PACE software for the identification of different soil units.

This classification is based on the training areas on image for the identification of spectrally separable soil units and other associated features.

Nine training areas were assigned to class the soil units and other features.

Among nine classes, five classes represent six soil series and remaining four classes represent rest of the associated features.

The training site for the six series had to be merged due to spectral inseparability of all the six soil units. In order to separate the soil units, five classes other features which include vegetation and settlements, forest cover, meander scar, and water bodies.

The supervised classification colour coded output shows the following classes.

Table-19 Colour Code and Soil Series and other Associated features on Supervised Classification Image

Colour code	Soil series / Other features
Cyan	UL soil
Bright white	YK and TYK soil (mixed)
Light pink	TYK soil
Yellow	ELL soil
Red	WUL and EUL soils
Light green	Vegetation and settlements
Dark green	Forest
Blue	Water bodies
Bluish green, light pink and white (mixed)	Geomorphic features (meander scar, point bar, channel bar)

Cyan colour UL soil series; bright white colour YK soil series; bright white with light pink colour (mixed) TYK soil series; yellow colour ELL soil series; red colour WUL and EUL soil series; light green colour vegetation cover and settlements; dark green colour represents forest cover; white bluish green with light pink represents geomorphic units (meander scar) and blue colour represents water bodies.

The above soil units and associated features can be seen in plate 42 and colour code, soil series / other features are presented in *table*-19, while their number of pixel, image per cent and area in ha. are presented in table-20.

From the table, it is clear that maximum area (8968.04 ha.) and number of pixels (67315) covered by the YK and TYK soil series and minimum area (287.63 ha.) and number of pixels (2159) covered by the UL soil series on 512 × 512 pixel image

Table-20 Statistics of Classified Image

Segments Name	Pixels	Image (%)	Area (ha)
Moist soil (geomorphic unit)	23256	9.02	3098.2806
Sandy soil (geomorphic unit)	33569	13.04	4472.23
River sand (YK &TYK)	67315	26.13	8968.0408
Saline/alkaline (UL) soil	2159	0.83	287.63277
Fertile (WUL & EUL) soil (Mod.)	49974	19.40	6657.7861
Fertile (ELL) soil (high)	2636	1.03	351.1811
Water bodies	36905	14.33	4916.6686
Forest	4373	1.70	582.59292
Settlement and other vegetation	37372	14.52	4978.8847
Total	**257559**	**100.00**	**34313.294**

CHAPTER-VII

IN SITU MEASUREMENTS

OF SPECTRAL REFLECTANCE OF SOILS

IN SITU MEASUREMENTS OF SPECTRAL REFLECTANCE OF SOILS

7.1 General Statement

Traditionally, the study of soils of an area includes the physical and chemical characteristics of soil and profile description.

In addition to these, the use of spectral measurement has further enriched these studies. The satellite image data is based on the assumption that each surface cover has a specific spectral response for the incident electromagnetic radiation (Mather, 1987).

A number of studies have shown information that the spectral reflectance of soil is useful in its identification and characterization in visible and infrared region of electromagnetic spectrum (Obukhov and Orlo 1964; Homes 1970; Cipra *et. al.*, 1971; Westin 1976a; Singh *et. al.*, 1977; Dwivedi *et. al.*, 1981; Singh and Dwivedi, 1989;).

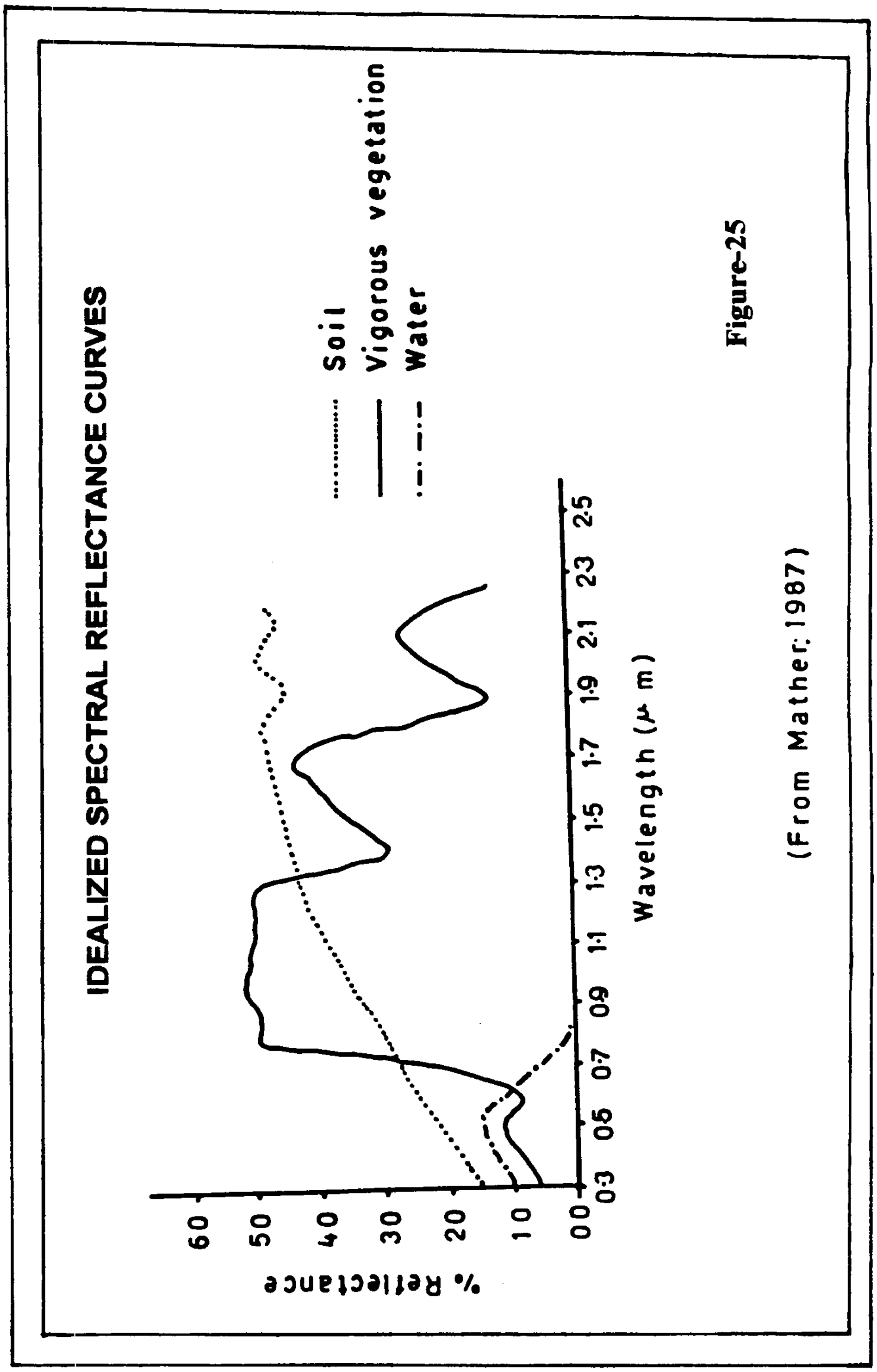
To describe the spectral reflectance of objects, spectral curves are drawn for 0.4 μm -to- 2.6 μm region of electromagnetic spectrum. These curves are the essential tool in choosing a sensor or a specific band for the description of surface and soil features.

Figure-25 shows important spectral reflectance curves for water, healthy vegetation and dry bare soil (Mather, 1987).

The spectral reflectance curves of soils in the Mathura district have not been studied so far. This chapter describes the detailed study of spectral reflectance of soil in different parts of the electromagnetic spectrum.

The spectral reflectance of soil in the Mathura district has been studied using ground based multi-band-ground truth Radiometer (Model-041, Chapter 4).

In the selection of soil for spectral measurements, more emphasis has been given on saline and saline-sodic soils rather than other soil types.



(From Mather; 1987)

Figure-25

The other soil associated parameters are: grain size distribution, moisture content and, vegetation cover. These parameters have been distinguished through its spectral response characteristics.

7.2 Factor Affecting Reflectance of Soil

The factors influencing the spectral reflectance of soil are: the moisture content, soluble cations and anions, the amount of organic matter, the amount of iron oxide, soil texture, the relative percentage of clay. These factors are complex, variable and interrelated with significantly influencing the spectral reflectance of soil. The relationships of these factors with spectral data have been described in the following sections.

7.3 Spectral Analysis of In situ Measurement

The spectral data have been collected (Chapter-4) for the spectral reflectance studies on three occasions of satellite overpass and their details are presented in chapter-4. These occasions are 6^{th} and 22^{nd} November, 1996 and 9^{th} January 1997, using portable ground-truth Radiometer (GTR).

The field spectral data are shown in table-21, which directly reveal the variation in the reflectance percentage of different categories of soil and their associated objects.

The spectral reflectance measurement has been accomplished in the study area for, normal soil, saline-sodic soil, moist and dry soil, green crops and green/dry grasses on different dates and times. The site characteristics have also been taken into account under natural field conditions.

The spectral reflectance percentage curves of the objects are indicative of the general trends, which show that with the increase of wavelength the spectral reflectance percentage also increase. The maximum reflecting energy was picked up particularly in band 4. The band 4 is very sensitive for soils rather than other bands in the spectral regions.

Figures: 26, 27 and 28 present the curves of spectral behaviour of different soils and associated objects which have been measured in the field by portable Radiometer (Chapter-4).

Table-21 Represents Radiometric Reflectance values at 10^{-2} Decade Factor.

		Spectral Reflectance bands corresponding to IRS LISS-II Sensor			
Soil texture	**Object conditions and village code**	**1 (0.45-0.52)**	**2 (0.52-0.59)**	**3 (0.62-0.68)**	**4 (0.77-0.86)**
C-Loam	Bare soil Strongly saline-sodic (dry), 225A	76.00	84.38	58.10	89.22
S-Loam	Soil with salt encrustation strongly saline (smooth surface), (246)	30.56	25.78	35.52	50.00
Loam	Bare soil, moderately saline-sodic (dry), 225B	21.22	23.49	30.58	41.72
C-Loam	Bare soil, moderately saline-sodic (dry), 225C	18.19	20.46	26.58	33.68
Clay	Bare soil, low-moderately saline-sodic, 225E	14.15	18.67	21.68	27.72
Loam	Soil with salt-encrustation (moist), 125F	34.00	31.26	29.26	28.95

Contd...

Loam	Sandy soil (unploughed, moist), 225D	73.69	79.17	85.97	97.86
Loam	Sandy soil (unploughed, rough) 18	60.00	58.10	64.74	67.11
Loam	Sandy soil (ploughed) dry, 102	24.62	27.06	30.77	49.85
C-Loam	Sandy soil with high moist (irrigated) 03	16.17	21.13	23.78	32.66
S-Loam	Sandy soil with moist (ploughed), 129	14.71	19.77	19.15	41.18
	Soil with grass cover	55.27	55.09	45.62	82.26
	Soil with poor crop cover (wheat)	50.00	51.57	28.75	84.22
	Soil with dry grass cover	18.19	20.46	27.28	41.84
	Soil with dry grass cover	20.38	20.15	18.08	57.28
	Soil with green grass cover	11.77	13.96	14.91	39.71
	Soil with poor crop cover (Yellowish wheat)	08.83	09.31	10.64	26.64
	Soil with poor crop cover (0.5 m height, wheat)	06.06	08.34	04.91	66.32

7.3.1 Salt Affected Soil

The basic idea of spectral reflectance has been introduced in section 7.2, while considering the spectral reflectance as shown in figure-25.

In this section, the spectral response information has been extracted by Radiometric observation. The observed values were used to described the spatial spectral response variation within the soil, soil cover and their subgroups.

The observed spectral response values for different categories of soil and its associated objects are given in table-21.

It is clear from the spectral response data that the spectral response percentage increases with the increase in wavelength. These wavelength correspond to IRS LISS-II; band 1, band 2, band 3, and band 4 respectively.

The variations in spectral response of soil in all spectral bands are due to the existence of principle soluble salt content i.e. cations: Ca^{++}, Mg^{++}, Na^{+}, anions: Cl^{-} and $SO_4^{--}$and exchangeable sodium, while other cations and anions are in small amounts namely: K, HCO_3^{-}, CO_3^{-} and NO_3.

The high concentration of these cations and anions concentrations are found in saline and saline-sodic soils while small amounts are in other types of soils.

However, the incident energy strikes these highly concentrated soils which directly reflects towards the sensor with high spectral reflectance while low spectra reflectance received by the sensor is due to low concentration of salt content in soils.

The reflection value in the four different bands measured by the radiometer (Table-21) and the reflectance curves drawn (Figure-26) shows that the highly saline-sodic soils has the highest spectral reflectance in all the four bands (0.42 - 0.52 μm., 0.52 - 0.59 μm., 0.62 - 0.68μm. and 0.77 - 0.86 μm.).

RADIOMETRIC MEASUREMENT OF SOILS AT 10^{-2} DECADE FACTOR

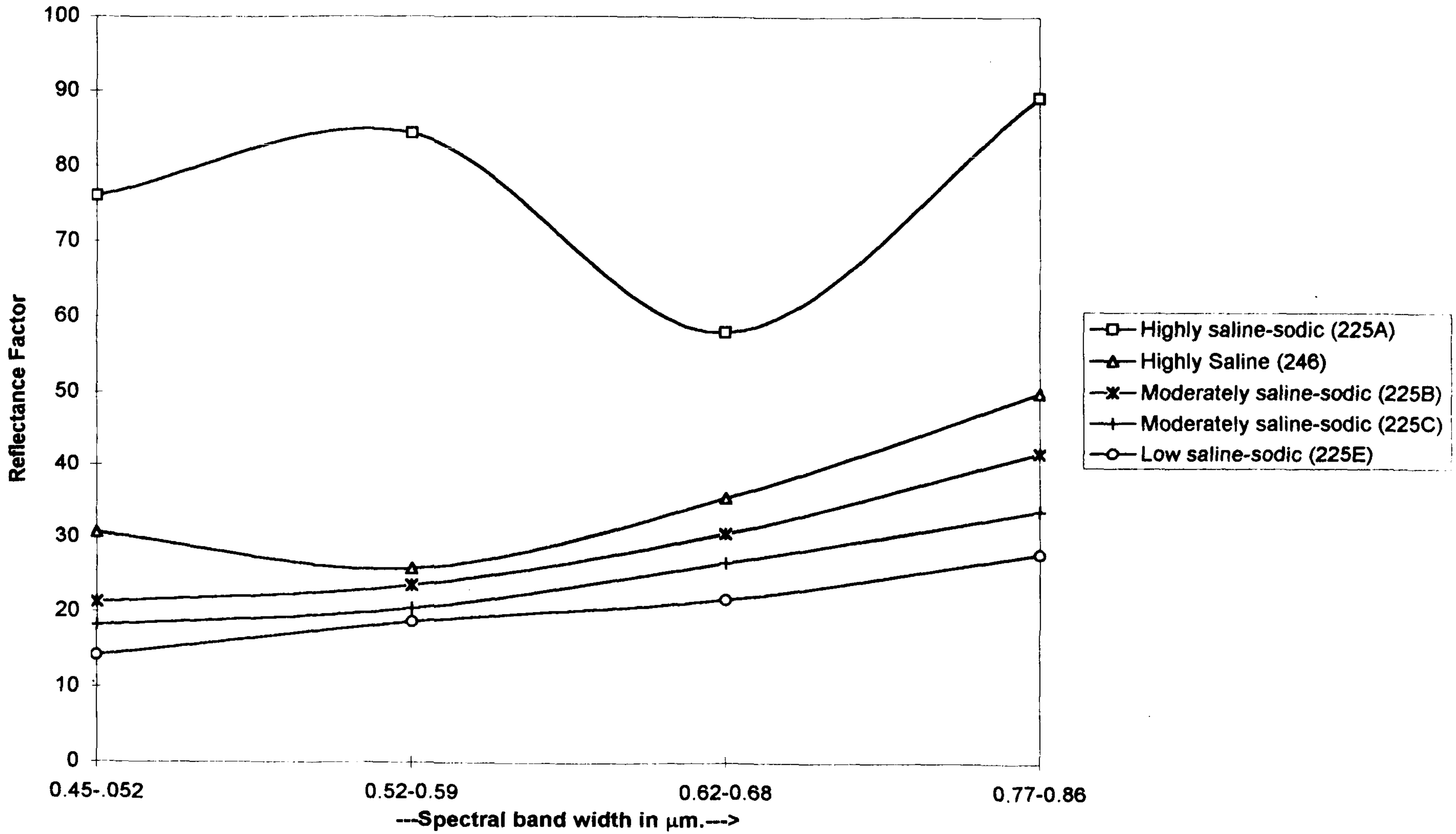


Figure - 26

In general, it is observed that the reflectance values increase with increasing wavelength. However, in the highly saline-sodic soil (225A) the reflectance drops slightly in bands 0.62-0.68 μm., even when it remains higher than the moderately saline-sodic and other saline soils.

The highly saline soil, which has high EC and low SAR shows the next higher reflectance out of five soils are studied. In this case also reflectance in general increase with wavelength except for a slight decrease in band 2 (0.52-0.59μm.) and then again it is increases. Two moderately saline-sodic soils studied (225B, 225C) also shows the increasing reflectance with increasing band width. The low saline-sodic soil has the least reflectance in all the four bands. Among all the five salt-affected soil studied.

The results also show that the wide variability in spectral reflectance of the five salt-affected soils studied. In the band 1 the reflectance varies from 14.15-76.00. In band 2 it varies from 18.67-84.38. In band 3 from 21.68-58.10 and in band 4 from 27.72-89.22. This wide variation in spectral reflectance could be due to the variation in the colour of the soil, texture extent of soluble salts and it efflorescence of the surface, it can be seen from the table showing the physical and chemical characteristics of the soil samples in tables-E-1, E-2, E-3 and E-4 (Appendix-E).

7.3.2 Effect of Tillage

The purpose of this section is to provide information about the effect of tillage on spectral response using the Radiometer that measured the electromagnetic radiation from the ploughed and unploughed soil surface (Figure-27).

Figure-27 illustrates the effect of surface roughness on visible and near-infrared region of the spectrum (0.45μm -to- 0.86 μm), as recorded from the ground based measurement.

The energy measured by Radiometer shows that the spectral response of undisturbed soil measured in the field under natural cloudless conditions are generally the inverse of that, measured from the ploughed or freshly exposed soil.

The highest spectral response for undisturbed soil at 10^{-2} decade factor, band 4 (0.77µm -to- 0.86 µm) has been observed.

Moreover, the spectral response recorded at 10^{-2} decade factor pertaining to in all the four bands have been studied and curves for these soils given in figure-27.

The Radiometric reflectance measurement values for five soils representing ploughed and unploughed conditions are given in table-21 and line graphical presentation in figure-27. It is observed that the two unploughed fields have the highest reflectance in all the four bands as compared to the other three soils. The reflectance were used in band 1 for unploughed field varied from 60.00 to 70.00, in band 2 from 58.10 to 79.00, in band 3 from 64.74 to 85.97 and in band 4 from 67.11 to 97.80. These soils also show the increasing reflectance with the increase in the wavelength. The plough fields having the dry soil showed lower reflectance than the unploughed field in all the four band.

Earlier studies in this direction were also carried out by Singh *et. al.*, (1981) for some typical Indian soils to separate ploughed soil from unploughed soil on the basis of spectral response.

Thus, it is clear from the illustrated curves that these spectral response curves are useful in the identification and characterization of specific soil properties to distinguish or separate ploughed soil and unploughed soil of different sensitive wavelength.

7.3.3 Effect of Moisture

In this section stress has been made to describe the influence of moisture namely: moist, highly moist and irrigated soil in the field under natural cloudless field condition at 10^{-2} decade factor (Figure-27).

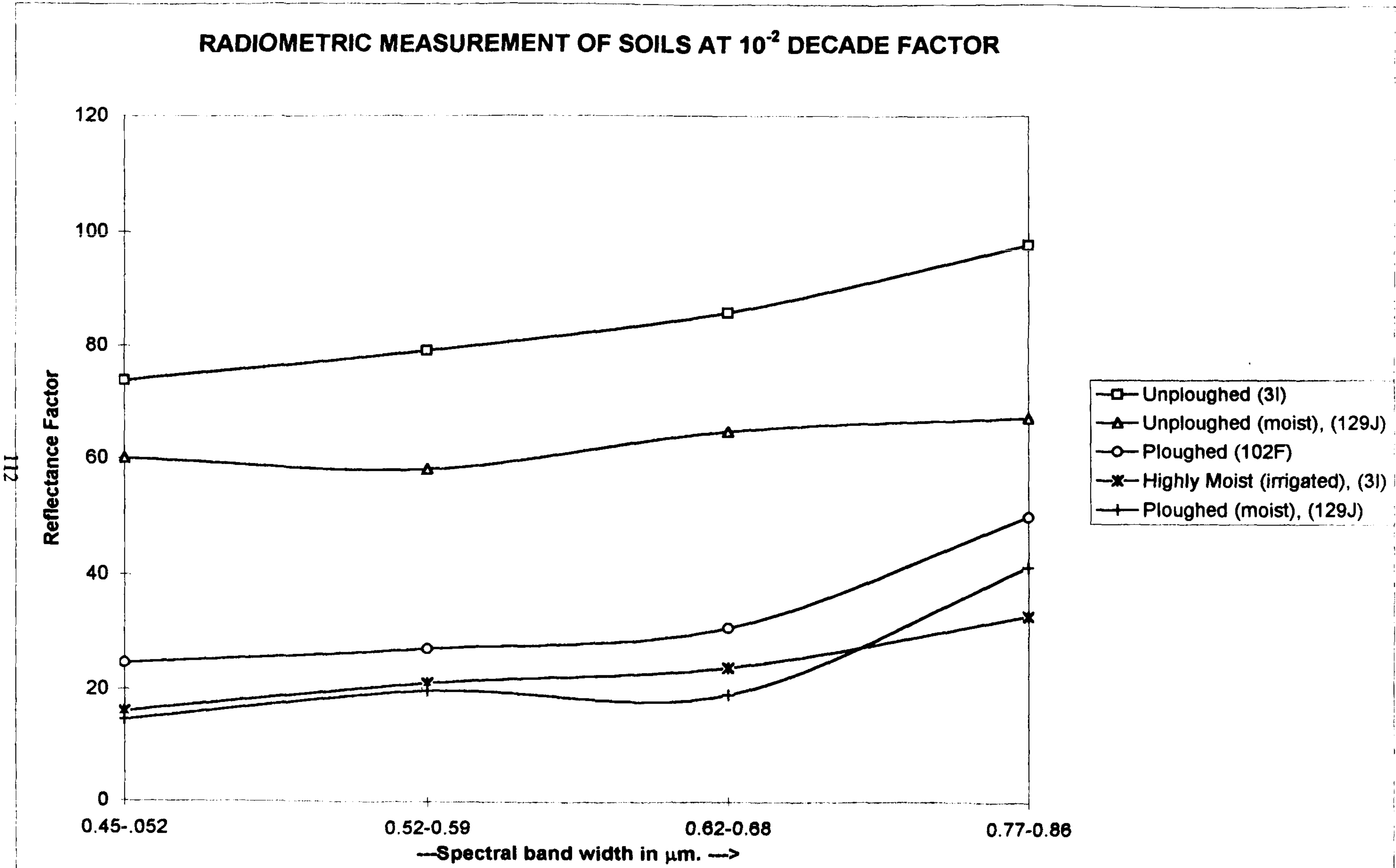

RADIOMETRIC MEASUREMENT OF SOILS AT 10-2 DECADE FACTOR
Reflectance Factor
120
100
80
60
40
20
0
0.45-.052
0.52-0.59
0.62-0.68
0.77-0.86
---Spectral band width in µm. --->
Unploughed (3I)
Unploughed (moist), (129J)
Ploughed (102F)
Highly Moist (irrigated), (3I)
Ploughed (moist), (129J)

Figure - 27

It is a common observation that most of the soils appear dark when wet than it is dry. These properties influence the reflection and/or emission of electromagnetic energy.

Soil moisture content has been found to create increasing or decreasing pattern of soil reflectance characteristics. Earlier researches have noticed certain linear relationships between absorbance and percentage of soil moisture (Bowers and Smith, 1972). Stoner and Baumgardner (1980), have evaluated results of statistical analysis as well as qualitative evaluation of soil reflectance/absorption characteristics of soil sample of different soil taxonomy order, and concluded that the region of the electromagnetic spectrum which displayed the highest correlation with the soil moisture corresponds to the range of 2.08 µm -to- 2.32 µm.

It has been demonstrated that moist soils have lower reflectance values than dry soils in the 0.4µm -to- 2.6 µm wavelength region (Hoffer and Johannsen, 1969). The work of Peterson *et al.*, (1979) revealed marked and distinct relationships among soil moisture tension and soil reflectance values.

Soil moisture curves have been generated from low moisture and high moisture sites (Figure-27) respectively by Radiometric measurements.

Figure-27 have shown the percentage of reflectance response of different moist soils and their corresponding sensitive bands for the soil moisture presence. The presence of soil moisture and the percentage reflectance response of moisture varies according to moisture content as well as Sun elevation during the observations.

The moisture have influenced in lowering the spectral reflectance and hence the moist soil both ploughed and unploughed have lower reflectance than the dry soil. The ploughed moist soil shows the lowest reflectance out of the five field for which spectral measurement have been made. Figure-27 represents that the curves drawn from the Radiometric measurement for moist soil condition in all the four bands.

The Radiometric reflectance measurement values for moist soils are given in table-21 and their graphical presentation in figure-27.

It is observed that moist soil (unploughed) has highest reflectance in the band 4 (97.86) and lowest (73.69), which increases with the increase of wavelength, moist soil (ploughed) shows the curves in which slight drop in spectral reflectance in band 3 (19.15), lowest and highest recorded in band 4 (414.18), while spectral reflectance recorded from the high moist soil (irrigated) represents highest in band 4 (32.66) and lowest in band 2 (16.17) respectively.

Thus, the moist soil have influenced in lowering the spectral reflectance and hence in moist soil both ploughed and unploughed have lower reflectance than other dry soils in the area. The ploughed moist soil shows the lowest soil for which measurements have been made.

These spectral response information are useful in the selection of bands for categorizing low and high water content and irrigated soils with respect to the different wavelength for porous and permeable, separation and identification of saline-sodic soils and non-saline-sodic soils.

7.4 Effects of Vegetation Cover

7.4.1 Grass Cover

The Radiometric observation has been made on dry grass cover and poor yellowish green grass cover for the spectral response. Figure-28 presents the effect of grass cover on spectral response.

The spectral response percentage from dry grass cover has resulted an increase from bands 1 and band 2 while slight decrease in band 3 and again sharp increases in band 4 (0.77 μm -to- 0.86 μm) (Figure-28). One of the reason for this behaviour is due to the reflection of incident energy by dry grass cover, recorded in sensor in the specific band 3 i.e., 0.62 μm -to- 0.68 μm The figure-28 indicates the absorption at wavelength 0.45 μm -to- 0.52 μm and 0.62 μm -to- 0.68 μm with the corresponding band 1 and band 3 respectively. The slight decrease in spectral response percentage is band 3, while sharp increase is in band 4.

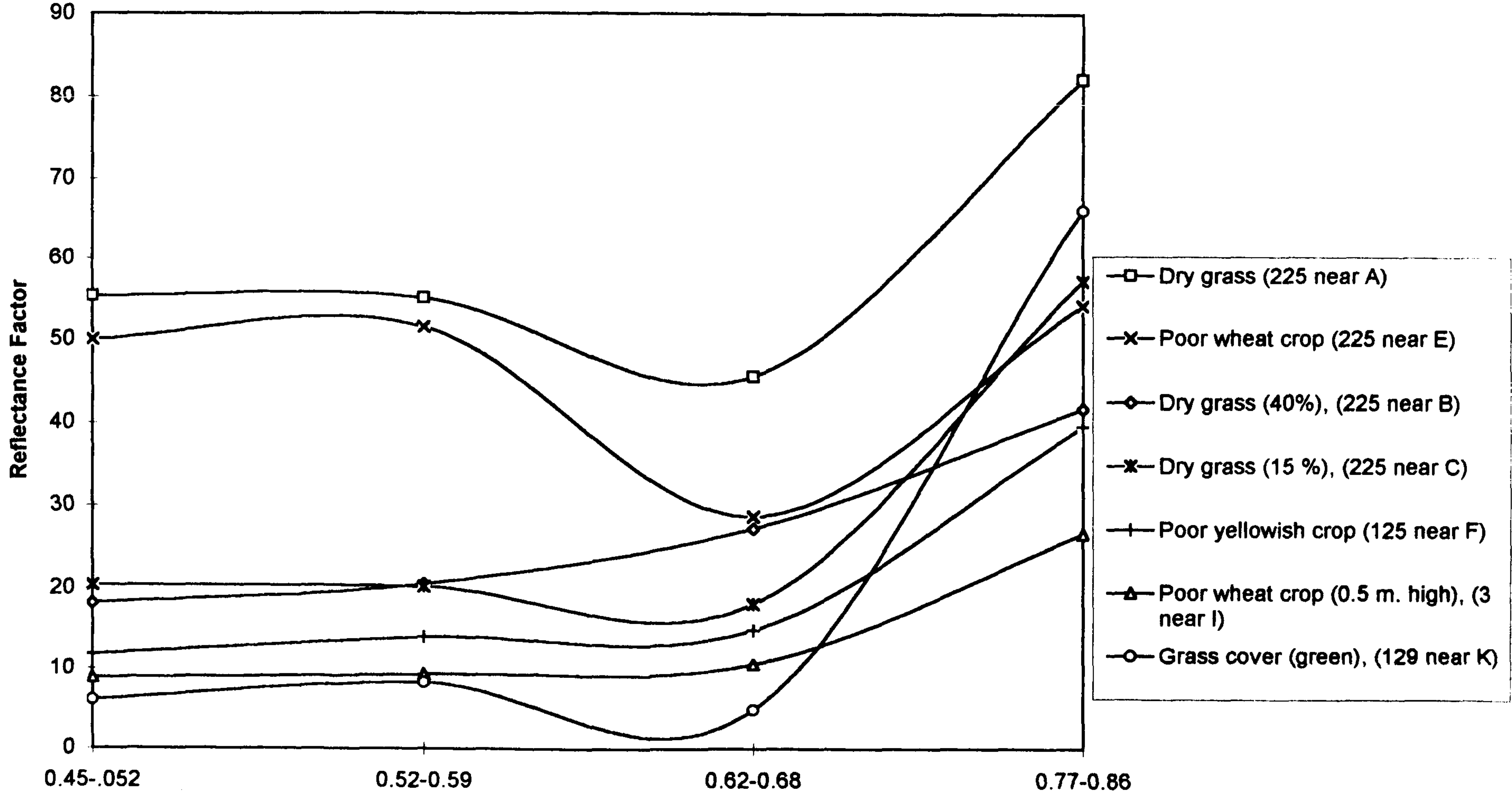
The Radimetric measurement of soil with different grass cover is presented in table-21 and the curves showing the pattern of reflectance is presented in figure-28. The grass cover on a soil surface effects the spectral properties since due to the cover the soil background reflectance is masked. The influence of grass cover on the soil reflectance will depend on the type of cover and its areal coverage. For example a dry grass will have a different influence as compared to green grass because of the characteristically difference in spectral behaviour of green vegetation. Similarly, as the per cent grass cover on the soil increases the reflectance will shoe the dominance of grass cover rather than the background soil. As can be seen from the above referred table and figure, soil with dry grass shows higher reflectance in the band 1 and band 2, a slight decrease in band 3 and a sharp rise in the spectral reflectance in band 4. The green grass as much lower reflectance than the dry grass in the band 1, band 2 and band 3 but tried to reach to its maximum in band 4, this is because of the higher reflectance in the infrared band (band 4) from the green vegetation.

7.4.2 Effect of Poor Wheat Crop Cover

This section describes the effect of poor wheat crop cover, having 0.5 meter height and 0.3 meter height on the soil reflectance. The effect on spectral response of salt-affected soil cover has been observed.

Figure-28 shows the increasing trend in the spectral reflectance with increasing wavelength in case of poor wheat crop. It is minimum in band 1 (0.45μm -to- 0.52μm) and maximum spectral reflectance in band 4 (0.77 μm -to- 0.86 μm).

RADIOMETRIC MEASUREMENT OF SOILS WITH VEGETATION COVER AT 10^{-2} DECADE FACTOR



---Spectral band width in μm. --->

Figure - 28

However, the difference in the amount in the spectral response per cent in band 3 and band 1 shows relatively low response while high spectral response is in band 2 and highest spectral response is in near-infrared, band 4 (Figure-28). These observations are in the case of both categories of poor wheat crop cover over saline-sodic soil in study area.

As is well known, the salt-affected soils support a poor crop, especially during the rabi crop season. In this season wheat is growing on the soil. Spectral measurement from poor wheat crop on the salt-affected soils is presented in table-21 and in figure-28, showing that the response from the wheat crop is low in band 1, band 2 and band 3. However, in band 4 reflectance increases due to the crop cover. Due to the poor crop the reflectance in band 4 does not increase so sharply as in the case of a wheat crop, where the soil background masked due to the coverage of the crop.

Thus, the spectral reflectance percentage curves exhibit the spectral reflectance seperability of different soils by measuring spectral response of the vegetation cover.

In general, it has been observed that the spectral response curves from different vegetation covers have integrated information from the height of the crop cover, grasses cover and soil background.

CHAPTER-VIII

DISCUSSION

DISCUSSIONS

The maps generated by visual interpretation of the remotely sensed data of the study area have been presented in figures: 4, 5, 6, 8, 9, 14 and 15, in situ spectral response measurements data at 10^{-2} decade factor for the area shown in table-21 and their spectral reflectance curves are illustrated in figures: 26, 27 and 28.

The physico-chemical characteristics of soil data from the study area are given in tables: E-1, E-2, E-3 and E-4 (Appendix-E) and their respective curves are shown in figures: 16 -to- 19.

8.1 Visual Interpretation of Satellite Data

Visual interpretation of satellite data for preparation of soil maps of Mathura District, UP.

A systematic interpretation of Landsat-TM image on 1:250,000 scale using photo-elements and ancillary information has lead to the preparation of a reconnaissance soil map of the District. Based on the image interpretation and ground truth collection including soil sampling and analysis, eight soil series in the District have been mapped. These are: Kupa soil series (KK), Mahaban Bangar soil series (TYK), Parkhan soil series (UL), Tarauli Janubi soil series (WLL), Pura soil series (WUL), Kolahar soil series (ELL), and Koyal soil series (EUL).

As is well known, the information require as on soil includes the physico-chemical characteristics of soils, which is not directly observable on the surface. What is observable on the satellite image is a composite reflectance of the surface soil material and some of the most dominating subsurface characteristics, which may some time be observed or otherwise be correlated by the profile characteristics.

Correlation of image interpretation units with the soil profile characteristics has been done in mapping the eight soil series in the District. Some of the soil mapping units may however contain soils other than the dominant series, which has been mapped. These may be termed as sub-dominant series in the mapping unit. Since the objective of the present study was to map the soil of the Mathura District at a reconnaissance level, only the dominant soil series has been mapped. In each of the soil mapping units profiles have been studied and correlated with the image characteristics.

It is observed that there is a good correlation between the soil mapping unit delineated base on image element and geomorphic features with the soil characteristics in Mathura District.

8.2 Digital Analysis

Statistical analysis of 512 × 512 pixels image of LISS II sensors representing a part of study area, has been analyzed in terms of mean DN values, correlation coefficient and variance covariance matrices, for four principal component image and their statistics are given in tables: 11 and 12 eigon values and eigon vectors are in tables: 13 and 14.

It is evident from the table-13 that the PC_4 accounts for 85.1048 percent of the total image variance, the PC_3 for 7.7060 percent, the PC_2 for 6.0515 percent and PC_1 represents only 1.1376 per cent of the image variance (Plates: 13 -to- 16). The PC_4 represents 'brightness', the PC_3 'greenness', the PC_2 differential (Δ) brightness and the PC_1 differential (Δ) greenness' the PC_1 contain very limited spectral information as it account for 1.1376 percent variance.

The white irregular patches (UL) in PC_1 and PC_2 images (Plates: 13 and 14), medium gray to dark tones are representing WLL and ELL soil series, while YK and TYK soil represent bright white to very bright tone, medium to smooth texture and irregular to regular pattern, associated with Yamuna river.

Bright white tones are common for salt affected soils, forest scattered vegetation cover, TYK, YK and settlement in the PC_1, PC_2 and PC_4 images respectively (Plates: 13, 14 and 16). Plate-15 represents best

PC_3 image for salt-affected (UL) soil, sandy soils (TYK & YK), WLL and ELL soil series. This image discriminate different feature and their respective soil reflectance response are closely depicted from the image.

The water course of Yamuna river with sand bar, point bar and meandering scar on either side of Yamuna river, has a typical NW- SE course of the bright white hue representing sandy soil (TYK & YK) in PC_3 image. Plate-16 illustrates PC_4 image containing mostly noise and bright white features. These bright features are salt affected soil, sandy soil, settlement, forest and scattered vegetation cover. The image of first, second and third principal components contain less noise.

Plates: 38, 39, 40 and 41 illustrate the IHS images, in which salt affected soils are discerned from non-salt affected soils except image in plate-39. This image having noisy appearance and some bright white strips.

Plate-38 shows image with bright white tonalities, providing best separation from highly salt-concentrated soils to soils having low salt concentration.

Plate-40 shows bright white to white hue with rough texture. In this image identification of water bodies, sandy soil (YK, TYK & KK), salt-affected soil scattered vegetation cover, forest and settlement, this image is difficult. It is useful for the separation of fertile soil (gray to dark tone) rather than other soils.

Plate-41 illustrates IHS transformation with improved separablity of soils, the pink area indicates the presence of soil salinity, while reddish areas depicted as a fertile soil with relative variation in colours, light green colour is similar for water bodies and forest cover.

The positive correlation and best separation of soil categories through spectral response analysis and are discerned for UL, YK and TYK soil series while negative correlation exists among ELL, EUL, and WUL soil series.

Plates: 32, 354, 36 and 37 represent FCCs and their band combinations for maximum separable soils with RGB & IR colour manipulations.

Plates: 31 and 35 illustrate the histograms (band 4) for band 3 and band 4 along with the FCC indicates high peakedness. The band 4 histogram symmetry about very high DN values. The histogram (band 3) has low peak, and it is slightly asymmetrical with its peak lying in higher DN values with its long tail in lower DN values. The histogram (band 2) illustrates the higher peak towards the higher DN values with steep slope and gentle slope towards the brighter end (DN) of gray level scale, while reverse of histograms can be seen in plate-34. The irregular salt-affected patches of soils are clearly seen in the north-western corner of the image. It separates from the adjacent soil with other associated features due to lack of vegetation cover, brighter DN values as compared to adjacent soils.

Plate-17 illustrates different categories of soils easily separable by combination of PC_4, PC_3 and PC_2 images.

Filtered images can be seen in Plates: 24, 25, 26, 27, 28 and 29. The better images are Gaussian filtered image (Plate-29) and edge sharpening filtered image (Plate-25) for soil interpretation, the rest of the filtered images subdued soil discernibility of soil class.

In unsupervised classifications, pixels are automatically classified and colours are assigned to discriminate the soils for identification purpose (Plate-43).

Sandy and Moist soils represented by magenta, grayish red shows high salt-concentrated soil surrounded by red. Red colour indicates low to moderate salt-concentrated soils, cyan colour indicates: forest, river sand and other soils. Blue colour shows water bodies, settlement and vegetation cover illustrated with bright white as well as very light pink; yellow shows fertile soil with high organic matter and green represents low to moderate fertile soil.

It is also clear from the unsupervised classified image that meander scar is subdued due to inhomogeneity of soils characteristics and their corresponding pixels.

The results of supervised classification techniques, are shown in Plates-42 and 43, while their statistics are in table-20. It is clear form the supervised classification image that various soils and their associated features can be depicted, based on spectral variability. The 257559 pixels of the image are categorized into nine separable classes, with respective to additive and subtractive colours. Besides this, colour code, soil series / other associated features are presented in table-19. Blue colour represents water bodies with 36905 pixels, dark green shows forest cover with 4373 pixels, moist soil is little bid dark cyan with 23256 pixels, sandy soil illustrate magenta with 33569 pixels, river sand (YK and TYK) shows white bright with 63715 pixels, moderately fertile (WUL and EUL) soil represented by red with 49974 pixels, high fertile (ELL) soil represents yellow with 2636 pixels, settlement and other vegetation cover present light green colour with 37372 pixels. It is evident from table-19 that maximum area (8968.04 ha.) and number of pixels (67315) covered by YK and TYK soil series and minimum area (287.63 ha.) and number of pixels (2159) covered by UL soil series on 512 × 512 pixels image.

8.3 In situ Spectral Response at 10^{-2} Decade Factor

The spectral reflectance per cent values for different soils and their associated objects are given in table-21, while their respective curves drawn from these values are shown in figures: 26, 27, and 28.

8.3.1 Effect of Saline/Alkaline Soils

The influence of salt-concentration on spectral properties of soils have been shown in figure-26. It can be seen that the spectral response increases with the increase in salt-concentration.

The highest spectral reflectance is observed (89.22) in strongly saline-sodic soil recorded on band 4 (0.77 -to- 0.86 μm) and the lowest spectral per cent (14.15) in low to moderate saline-sodic soil on band 1 (0.45 -to- 0.52 μm) at 10^{-2} decade factor (Figure-26). It is evident from the figure-26 that the separation is poor in band 2 and band 1, while good in band 4 (0.77-0.86μm).

These observations show that the spectral reflectance per cent and their composite curves (Figure-26) are useful for selecting the proper bands for separation of salt-affected soil and their magnitude of salt concentration i.e., Typic Natrustalfs, Typic Natraqualfs and Aquic Natrustalfs.

The strongly-saline-sodic soil reflect more incident energy (Figure-26) as compared to moderately-saline-sodic soils. The results of these measurements are very close to the findings of Singh (1987) and Dwivedi) *et. al.*, (1981).

8.3.2 Effect of Vegetation Cover

Spectral response curves of vegetation cover over salt-affected soils are presented in figure-28. These curves show the incident energy is low in band 1 and band 2 while it is high in band 4. Similar views have been reported by Rao *et. al.*, (1995) in their studies for areas other than alluvial plain of Mathura district. The spectral response for grass / shrubs have been illustrated by curves in figure-28 and their values in per cent are shown in table-21. It is evident that spectral response decreases in band 3 (0.62 -to- 0.68 μm) and increases in other bands. Figure-28 vividly demonstrates the composite curves of grasses and crop covers wherein separation within grasses is clearly seen. The separation is poor in wheat crop cover (0.5m. ht) and poorly crops are not observed in band 4, while well discriminated grasses and shrubs are in band 4 with high spectral response.

8.3.3 Effect of Tillage

Effect of tillage on spectral response is illustrated by composite curves in figure-27, and their values in table-21. The lower spectral response have been observed in ploughed conditions when compared with unploughed conditions of soils. It is observed that some part of incident radiant energy penetrates into intra-aggregates and becomes diminishes completely. Similar observations have been reported by Dwivedi, Singh and Raju (1989), Orlo (1996) and Stoner *et. al.*, (1971) for areas other than Mathura district, U.P.

8.3.4 Selection of Bands for Discriminating Different Soils

This sections deals with the sensitive spectral response bands for discriminating soils having salt concentration that have been measured at 10^{-2} decade factor.

The principal soluble salt concentration occurring in the A-horizon are the predominating cations: Ca^{++}, Mg^{++}, K^{+}, and Na^{+}; anions: Cl^{-} and So_4^{-} together with HCO_3^{-}, and CO_3^{--}. Singh *et. al.*, (1989) have also carried out spectral bands selection by using In Situ radiometric measurements for characterizing the soil salinity-sodicity status and monitoring the dominance of principal soluble salt concentration in Indo-Gangatic alluvial soils.

Figure-26 illustrates the spectral response percentage of salt affected soil in red band (0.45 -to- 0.52 μm) is lower and in near-infrared bands (0.77 -to- 0.86 μm) is higher, while the range of spectral response per cent is much less in green band (0.52 -to- 0.59 μm) it range from 18.67 -to- 84.38 per cent i.e. separation is poor in this band, whereas the separation is better in near-infrared band which separate strongly-saline-sodic from strongly saline and moderately saline soils to non-salt-affected soils.

However, the curves in figure-26 illustrate the measured reflected energy with different sensitive bands. It is evident from the illustrated curves that maximum energy is reflected from the highly salt concentrated soils.

Moreover, the curves in figure-26 provide highest discrimination between the strongly and moderately saline-sodic soils. This is attributed to the fact that sodicity is determined by the amount of free carbonates which has a strong absorption in red and green bands (0.45 -to- 0.52 μm and 0.52 -to- 0.59 μm) respectively.

In general, the maximum energy is sensed in near-infrared band than in red, green and blue bands from the salt-affected soil having high concentration of cations and anions of principle soluble salts. Additionally, the band 4 is sensitive for the discrimination of strongly-saline-sodic soil, saline and moderately saline-sodic soils.

8.4 Physico-Chemical Characteristics of Soils

The soil of the study area has been grouped into eight soil series viz. TYK, YK, KK, ELL, WLL, EUL, WUL and UL. These series are delineated on the basis of remotely sensed data, physiognomic, physiography, geology, geomorphology and physico-chemical characteristics. The soil series and their respective physico-chemical characteristics are given in tables: E-1, E-2, E-3 and E-4 (Appendix-E).

Few physico-chemical parameters have been determined for soil series and their values are presented in tables: E-1, E-2, E-3 and E-4 (Appendix-E) and in figures: 16 -to- 19 to asses the general suitability of soils. But it is evident from the tables that the 'UL' series have relative higher pH, CEC, SAR, Na^{++} when compared to other soil series. These characteristics low the current potential capability of soils that cause a decrease in the fertility status.

Table-22 Classification of Salt-affected Soils, Indo-Gangetic Alluvial Plain, Mathura District.

Sl. No.	Soil categories	EC dSm^{-1}	ESP	pH	Reflectance	Textural class	Remarks
1	SALINE	>4.0	<15	7.0-8.5	Moderate to High response	Fine to Medium with kankar (*Nodules*)	Excess soluble salts: Cl^-, SO^{--}_4, Na^+, Ca^{++} and Mg^{++}.
2	SALINE-SODIC	>4.0	>15	≥8.5	High to V. high response	Fine to V. fine with kankar (*Nodules*)	Soil toxicity to plants increase.
3	SODIC	<4.0	>15	>8.5			Unsatisfactory soil physical & chemical condition.
4	NORMAL	<4.0	<15	6.0-8.0	Low to V. low response	Medium to Coarse	Satisfactory soil conditions.

8.4.1 Morphological Characteristics

The morphological descriptions of representative soil profiles are given in Appendix-A and their respective profiles are given in figures: 23 and 24 (a -to- h).

It was observed that few horizons have very content of Cl^-, SO_4^{--} Na^{++} , Mg^+, pH, ESP and EC in profiles.

The littering and paludisation are high in ELL, WLL, EUL, and WUL, and low in TYK, KK YK and UL soil profiles.

The lessivage process is low in 'A' horizon, while moderate to high in 'B' and 'C' horizons. This process indicates (a) depletion of clay with admixture of mud in 'A' horizon, (b) enrichment of clay with admixture of mud in 'B' horizon rather than 'C' and 'A' horizons and, (c) total fine clay ratio in 'B' horizon is higher than 'A' horizon.

The calcic horizons are developed at shallow depth as shown in figures: 23 and 24 and their respective profiles: (a & b), and (h).

8.5 Detrimental Effects of Canals

The network of irrigation system in the study area through canals is of approximately 12,655 hectare. The main canals are namely: the Agra canal and branches of Mat canal and their distributaries passing through the study area (Figure-9). Water of these canal soaks into the ground under the bed of an unlined canal with regular supply of water. The level of groundwater in the area irrigated by canals rises, in some places where the perennial unlined canals flow at the ground level and between raised high banks, the water-table is reached near the surface and renders the once cultivable or fertile soil completely water-logged.

The complete saturation of soil with canal-water gives rise to swampy appearance, where the water-table remains a few feet below the ground.

However, the capillary action brings white encrustation to the surface during dry condition in the area. This results in high concentration of salts in the soil and thin layers of salt patches on the soil surface were observed along the canals (Figures: 14 and 15) particularly during the dry months of the year. The encrustation particularly observed in the immediate vicinity of Agra Canal and Mat Canal.

The effect of the canal water increases considerably the intensity of salts in the effected patches and their area in the irrigated tract, due to irrigation activities and other misuse.

Rise of groundwater in the area where the groundwater has high proportion of sodium relative to divalent cations and/or has residual alkalinity further results in accumulation of sodium in the root zone. Moreover, Roads and built-up areas are also affected because of soft wet soil in the area. The shallow aquifer and well water, too is affected and sometimes is rendered unfit for drinking, for industry and as well as for agriculture.

SUMMARY & CONCLUSION

SUMMARY AND CONCLUSION

Remotely sensed data were utilized through statistical analysis for the study of soils of semi-arid ecosystem of Mathura district, U.P.

The soil information was extracted by visual interpretation of satellite image, computer aided digital classification, in situ spectral measurement, site characteristics study and physico-chemical data of soils. These data were acquired at different times with different spectral, spatial and temporal resolutions. This synergetic approach was found useful in assessing the soils of the semi-arid ecosystem of the Indo-Gangetic Alluvial Plain of Mathura District.

Soil mapping at 1:250,000 scale was found, feasible from visual interpretation of Landsat-TM data, as it provide sufficient details about soils and other associated features when used in conjunction with the ancillary data, spectral reflectance of soils and ground information. Eight soil mapping units were identified and the dominant soil series in each mapping unit was characterized by studying morphological and physico-chemical characteristics.

The study demonstrates the utility of the remotely sensed data in order to delineate the soil categories in the preparation of reconnaissance level map. The map shows the relationships between spectral characteristics and the soils of the Indo-Gangetic Alluvial Plain in this semi-arid ecosystem area. The map also aids in assessing the magnitude of soil degradation.

The digital image processing of IRS-1A LISS-II data of an area covering 512 × 512 pixels from Mathura district using MGE and EASI / PACE softwares, various enhancement techniques and supervised as well as unsupervised classification was attempted on this sub-image of Mathura district. The study show the utility of various enhancement techniques viz., single band analysis, principal component, FCCs, filtering, IHS and IHS transformation in extracting the soil information by making some of the features more discernable. Single enhancement could provide the limited soil information. However, no enhancement technique could provide the enhanced image for all the features. This shows that depending on the area, and the features could be enhanced, different enhancement techniques will have to be used.

The unsupervised classification provided the information on some of the soil series. Due to the spectral intermixing of different soil series, all the soils could not be classified in the unsupervised classification output.

However, the saline-sodic soils could be easily identified and within this category, two classes of salinity and sodicity could be identified in the unsupervised classification.

The supervised classification using maximum likelihood classifier on EASI / PACE software was done to see if all the soil series mapped in the area could be classified based on the training site provided for the existing soil classes. The results showed that due to surface cover variability some of the soil classes where intermixed and hence could not be separated on the supervised colour coded output.

It is possible that at a more detailed level of mapping some of the intermixing seen on the supervised output could be separated, leading to the identification of six soil series.

In order to study, the spectral characteristics of some of the soils of Mathura district, in situ spectral reflectance measurements were done using Radiometer (model-041). This Radiometer measure reflectance in the four bands similar to IRS-1A LISS-II bands. Spectral measurements of surface soil from the different types of saline-sodic soils, vegetation cover, tillage practices and grass cover were studied. The study showed that using in situ measurements, three categories of saline-sodic soils and one category of saline soil could be differentiated. The influence of vegetation on the spectral reflectance of soils could be studied which show that the increasing vegetation cover masked the soil properties. Tillage practice like ploughing had an influence on the spectral characteristics of soil. The spectral response in all the bands were lower in the ploughed fields as compared to the unploughed fields. The influence of moisture on the spectral characteristics of soil was also studied which showed marked reduction in reflectance of soils due to wetting.

The study has thus provided an overall information on the soils of Mathura district in relation to the spectral behaviour.

The soils of the semi-arid ecosystem are faced with the problem of wind erosion and soil salinization and sodication.

It is therefore, necessary that the proper measures be taken for managing these soils in order to achieve sustainable production and to maintain ecological balance. Remotely sensed data has proved its utility in providing this valuable information for achieving these objectives.

The utility of the delineated soil categories and spectral response relationships shows that this technique could be utilized in other adjoining areas, which will be helpful in execution of micro-level planning, and in management at village level for the sustainable use of soils.

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APPENDICES

APPENDIX-A

Table: 1-A

PROFILE NO.-I

SOIL SERIES	:	Mathura Khadar (YK).
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Gentle to Moderate (3 - 10 %).
WATER TABLE	:	6.65 meters (Pre-monsoon) 5.40 meters (Post-monsoon).
GEOLOGY	:	Yamuna Recent Alluvial Formation.
GEOMORPHOLOGY	:	Recent flood plain of Yamuna river.
ELEVATION (a.m.s.l.)	:	168.00 meters.
LOCATION	:	Tehsil Near Mathura Khadar village, Mathura.

Depth (cm)	Horizon	Main Characteristics
00-15	A_p	Light grey (5Y 7/1, 7/2), loamy sand platy structure, moist, friable in nature, slightly sticky, porosity and permeability high, roots present.
15-35	C_1	Grey (10 YR 5/1), wavy boundary, fine sand, granular, slightly hard and sticky, porosity and permeability high, roots present.
35-75	C_2	Greyish brown (10 YR 5/2), fine sand, slightly hard, and slightly sticky, porosity and permeability high, thin roots present.
75-119	C_3	Dark greyish brown (10 YR 4/2), and fine sand, granular to sub-angular, porosity and permeability high, fine roots present.
119-154	C_4	Dark brown (10 YR 3/3), clay loam, angular to spheroidal, hard and compact, permeability and leaching low, very fine roots present.

Table: 2-A

PROFILE NO.-II

SOIL SERIES	:	Kupa (KK).
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region : Ganga - Yamuna Interfluve.
SLOPE	:	Gentle to moderate (3-10 %).
WATER TABLE	:	16.95 meters (Pre-monsoon) 5.40 meters (Post-monsoon).
GEOLOGY	:	Yamuna Recent Alluvial Formation.
GEOMORPHOLOGY	:	Recent flood plain of Karban River.
ELEVATION (a.m.s.l)	:	172.00 meters.
LOCATION	:	Near Kupa Village, Sadabad tehsil.

Depth (cm)	Horizon	Main Characteristics
00-20	A_p	Light brown (7.5 YR 6/4), loamy sand; granular spheroidal; friable; slightly hard, and slightly stick; porosity and permeability high; fine roots present.
20-45	C_1	Brown (7.5 YR 5/2), silty loam; spheroidal to angular, medium hard; moderately sticky; permeability and porosity medium; few roots present.
45-106	C_2	Greyish brown (10 YR 5/2), sandy loam angular to sub-angular; uneven boundary, friable, slightly hard, and sticky, porosity and permeability high, roots present.
106-170	C_3	Dark Greyish brown (10 YR 4/2), fine sand; granular to spheroidal slightly hard; non-sticky; porosity and permeability high, roots present.

Table: 3-A

PROFILE NO.-III

SOIL SERIES	:	Mahaban Bangar (TYK).
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga - Yamuna Interfluve.
SLOPE	:	Gentle to moderate (3-10 %).
WATER TABLE	:	14.40 meters (Pre-monsoon) 14.30 meters (Post-monsoon).
GEOLOGY	:	Newer Alluvial Formation.
GEOMORPHOLOGY	:	Terrace zone of Yamuna.
ELEVATION (a.m.s.l.)	:	177.00 meters.
LOCATION	:	Near Mahaban Bangar village, Sadabad tehsil.

Depth (cm)	Horizon	Main Characteristics
00-20	A_p	Light yellowish Brown (10YR 6/4), sandy loam; platy, uneven boundary, friable; slightly hard, compaction and slightly sticky; permeability and leaching high, roots present.
20-41	C_1	Yellowish brown (10YR 5/4), loamy sand; angular to spheroidal; few flaky minerals present; uneven boundary; slightly hard and slightly sticky; permeability and porosity high; fine roots present.
41-85	C_2	Dark yellowish brown (10YR 4/4, 4/6), loamy sand; uneven horizon boundary; friable; granular to sub-angular, slightly hard; and compact; permeability and leaching high; *few* thin roots present.
85-118	C_3	Dark yellowish brown (10YR 3/4), loamy sand; granular to spheroidal; friable; slightly hard and slightly sticky; permeability high; few roots present.
118-161	C_4	Dark yellowish brown (10YR 4/4), loamy sand; granular to spheroidal; slightly hard and sticky; permeability high; few fine roots present.
161-180	C_5	Light brown (7.5YR 6/4), sandy; granular to sub-angular; slightly hard and sticky; porosity and permeability high.

Table: 4-A

PROFILE NO.-IV

SOIL SERIES	:	Parkhan [(*Usar Land* (UL)]
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Shallow with flat topography (< 1 %).
WATER TABLE	:	4.90 meters (Pre-monsoon) 3.60 meters (Post-monsoon).
GEOLOGY	:	Aligarh Older Alluvial Formation.
GEOMORPHOLOGY	:	Aligarh Older Plain.
ELEVATION (a.m.s.l.)	:	180.00 meters.
LOCATION	:	Near Parkhan village, Mathura tehsil.

Depth (cm)	**Horizon**	**Main Characteristics**
00-15	**A_1**	Light olive brown (2.5Y 5/4), silty-clay-loam; platy, angular to spheroidal; slightly sticky, hard and compact; medium porosity and permeability; leaching low; saline-alkaline in nature; diffuse and uneven boundary.
15-35	**A_2**	Greyish brown (2.5 Y 5/2), silty-loam, angular to spheroidal; slightly compaction and stickiness; porosity high, permeability and leaching low; few fine roots present.
35-80	**B_1**	Greyish brown (2.5 Y 5/2), clay-loam; angular to spheroidal; hard and compact; porosity high; permeability and leaching very low; small *kankars* present.
80-115	**B_2**	Light olive brown (2.5 Y 5/4), clay-loam; angular to spheroidal plasticity and stickiness high; compaction and porosity high; permeability and leaching low; *kankars* present.
115-160	**C**	Greyish brown (2.5 Y 5/2), silty-clay loam; angular to spheroidal, compact, permeability and leaching low to very low, porosity high, *kankars* present.

Table: 5-A

PROFILE NO.-V

SOIL SERIES	:	Tarauli Janubi (WLL)
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Plain with very gentle slope (< 3%).
WATER TABLE	:	7.40 meters (Pre-monsoon) 6.25 meters (Post-monsoon).
GEOLOGY	:	Aligarh Older Alluvial Formation.
GEOMORPHOLOGY	:	Aligarh Older Alluvial Plain.
ELEVATION (a.m.s.l.)	:	184.00 meters.
LOCATION	:	Near Tarauli Janubi village, Chhata tehsil.

Depth (cm)	Horizon	Main Characteristics
00-20	A_1	Greyish brown (2.5 Y 5/2), sandy loam; angular to spheroidal; few flaky mineral present; compaction and stickiness low to moderate; permeability and leaching high; roots present.
20-45	A_2	Light brownish grey (2.5 Y 5/2), silty loam; angular to spheroidal; compaction and stickiness high; permeability and leaching low; few thin roots present, small *kankars* present.
45-102	B_1	Dark greyish brown (10 YR 4/2), clayey-loam; angular to spheroidal; compaction and stickiness high; porosity moderate; permeability and leaching low; small scattered *kankars* and fine roots present.
102-140	B_2	Dark yellowish brown (10 YR 4/4), loamy; angular to spheroidal; compaction and stickiness moderate; permeability and leaching normal.
140-170	C	Light brownish grey (10 YR 5/2), silty-clay-loam; granular to sub-angular; compaction and stickiness moderate to high; porosity moderate; permeability and leaching low.

Table: 6-A

PROFILE NO.-VI

SOIL SERIES	:	Pura (WUL)
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Very gentle to gentle (1-5 %).
WATER TABLE	:	8.10 meters (Pre-monsoon) 6.40 meters (Post-monsoon).
GEOLOGY	:	Varanasi Older Alluvial Formation.
GEOMORPHOLOGY	:	Varanasi Older Alluvial Plain.
ELEVATION (a.m.s.l.)	:	174.00 meters.
LOCATION	:	Near Pura village, Mathura tehsil.

Depth (cm)	Horizon	Main Characteristics
00-15	A_p	Light brown (7.5 YR 6/4), sandy loam; granular and spheroidal; compaction and stickiness low; permeability and leaching high; roots present.
15-40	B_1	Brown (10 YR 5/3), loamy; angular to spheroidal; uneven boundary, compaction, hardness and stickiness low; permeability and leaching high; few roots present.
40-90	B_{31}	Dark brown (7.5 YR 3/2), sandy loam; granular; compaction and stickiness medium; permeability and leaching medium; fine roots present.
90-150	B_{32}	Dark yellowish brown (10 YR 4/4), sandy loam; granular to spheroidal; compactness and stickiness low; permeability and leaching high.
150-175	B_{33}	Brown (10 YR 5/3), loamy sand; granular; friable; compaction and stickiness low; permeability and leaching high.

Table: 7-A

PROFILE NO.-VII

SOIL SERIES	:	Koyal (EUL)
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Very gentle to gentle (1-5 %).
WATER TABLE	:	7.70 meters (Pre-monsoon) 6.20 meters (Post-monsoon).
GEOLOGY	:	Varanasi Older Alluvial Formation.
GEOMORPHOLOGY	:	Varanasi Older Alluvial Plain.
ELEVATION (a.m.s.l.)	:	177.00 meters.
LOCATION	:	Near Koyal village, Mat tehsil.

Depth (cm)	Horizon	Main Characteristics
00-18	A_p	Yellowish brown (10 YR 5/4), fine sandy loam; concretion and mottles absent; granular structure; compaction and stickiness low; permeability, porosity and leaching high; roots present; micacious particles also present.
18-47	B_1	Brown (7.5 YR 5/2), loam, angular to spheroidal; compaction and stickiness medium; permeability and leaching medium; thin roots present, wavy boundary.
47-85	B_{21}	Dark brown (7.5 YR 3/2), loam; angular to spheroidal; firm and sticky; permeability and leaching medium; fine roots present.
85-130	B_{22}	Light yellowish brown (10 YR 6/4), loam; angular to spheroidal; hard and sticky; permeability and leaching medium; few fine roots present.
130-165	B_{23}	Yellowish brown (10 YR 5/4, 5/6), silty loam; angular to spheroidal; compaction and stickiness medium; permeability and leaching medium; few fine roots present.

Table: 8-A

PROFILE NO.-VIII

SOIL SERIES	:	Kolahar (ELL)
PHYSIOGRAPHY	:	Indo-Gangetic Alluvial Plain. Sub-region: Ganga-Yamuna Interfluve.
SLOPE	:	Plain to Very gentle (< 3%).
WATER TABLE	:	9.05 meters (Pre-monsoon) 8.30 meters (Post-monsoon).
GEOLOGY	:	Aligarh Older Alluvial Formation.
GEOMORPHOLOGY	:	Aligarh Older Alluvial Plain.
ELEVATION (a.m.s.l.)	:	185.00 meters.
LOCATION	:	Near Kolahar village, Mat tehsil.

Depth (cm)	**Horizon**	**Main Characteristics**
00-15	**A_p**	Light greyish brown (10 YR 5/2), loam; angular to spheroidal; compaction and stickiness medium; permeability and leaching low to moderate; roots present, uneven boundary.
15-45	**B_1**	Light olive brown (2.5 Y 5/6), silt loam; angular to spheroidal; compaction and stickiness moderate; permeability and leaching low to moderate; fine roots present; uneven horizon boundary.
45-115	**B_2**	Light grey (2.5 Y 7/2), clay loam; flaky, angular and spheroidal; compaction and stickiness moderate to high; permeability and leaching moderate; few fine roots present; small scattered *kankars* (*Nodules* of calcium carbonate) present.
115-180	**B_3**	Dark greyish brown (2.5 Y 4/2), silty-clay-loam; angular to spheroidal; compaction and stickness moderate; permeability and leaching low; few fine roots present.

APPENDIX - B

Table: B-1 Spectral Range and Application of IRS-1A data.

Table: B-1

No. of bands	Spectral Range (microns)		Applications
1	0.45 - 0.52	i.	Coastal environment studies (Coastal morphology and sedimentation studies).
		ii.	Soil/Vegetation differentiation
		iii.	Coniferous/ Reciduous vegetation discrimination.
2	0.52 - 0.59	i.	Vegetation vigour,
		ii.	Rock/Soil discrimination
		iii.	Turbidity and bathymetry in shallow waters.
3	0.62 - 0.68	i.	Strong chlorophyll absorption leading to discrimination of plant species.
4	0.77 - 0.86	i.	Delineation of water features
		ii.	Landform /geomorphic studies.

Table: B-2 Major Specifications of IRS-1A Payload and Optical Parameters.

Table: B-2

Sl. No.	Parameters	LISS-I	LISS-II
1	Ground Resolution (mts.).	72.5	36.25
2	Number of bands.	4	4
3	Spectral Range (microns).	(Visible & NIR) 0.45-0.86	(Visible & NIR) 0.45-0.86
4	Integration Time (m sec.).	11.2	5.6
5	Instantaneous field of view (u rad.).	80.2	40.1
6	Swath (km.).	148.48	146.98 Combined Swath of LISS-IIA & LISS-IIB
7	Number of Radiometric Levels.	128	128
8	Data Rate (MbPs).	5.2	2×10.4
9	Configuration.	Refractive	Refractive
10	Focal Length (mm).	162.2	324.4
11	Field Angle (deg.).	9.4	4.7

Table: B-3 IRS-1A Data Handling System Specifications.

Table: B-3

Parameters	LISS - I	LISS -II A & B
Bit Rate	5.2 MbPs	10.4 MbPs
Word Length	7 bits/ word	7 bits/word
No. of words per pixel	4 words (Bands 1 to 4)	4 words (Bands 1-4)
No. of pixel per frame	2048	2048
No. of words per frame	8328	8328
Frame Sync. Code	127 bit PN sequence	
Randomizing Code	812 bit PN sequence with MNFS 1023 - bit PN sequence without MNFS.	
Minor Frame Sync.	7 bits 0101110 once in 117words	
Output Code	PCM RNRZ (S)	PCM RNRZ (L)
Modulation Scheme	PCM / BPSK	PCM / QPSK
RF band	S-band	X-band
RF Power Out	37 dB m	43 dB m.

APPENDIX - C

Major Specifications of LANDSAT

The launch of LANDSAT-1 by the National Aeronautics and Space administration (NASA) in July 1972 ushered in a new era in earth observations. LANDSAT-2 & 3 followed in January 1975 and March 1978, respectively. LANDSAT-D, which will become LANDSAT-4 after a successful launch, was scheduled to be placed in polar orbit during the fourth quarter of 1982. LANDSAT-1, 2, & 3 are in near polar, Sun-Synchronous orbit at an altitude of approximately 920km. The orbital and sensor designs are such that each satellite has the capability of observing the entire surface of the earth every 18 days. Each image obtained by the LANDSAT sensor covers an area of 185×185 km (34,000 sq. km.). Each LANSAT is equipped with some combination of the following sensors: return beam vidicon camera (RBV), multi-spectral scanner (MSS), and thematic mapper (TM). Basic specifications of the sensors are return beam vidicon (RBV), multi-spectral scanner (MSS) and thematic mapper (TM) on LANDSAT-1, 2, 3 and D.

Table: C-1

LANDSAT	Sensor	Spectral Band (μm)	Description	Spectral Resolution
1, 2,	RBV	0.475 - 0.575	Visible blue, green	80
		0.580 - 0.680	Visible orange,	80
		0.690 - 0.830		80
3		0.505 - 0.750	Red near-infrared	80
1, 2, 3, D	MSS	0.5 - 0.6	Visible green	80
		0.6 - 0.7	Visible red	80
		0.7 - 0.8	Near-infrared	80
		0.8 - 1.1	Near-infrared	80
		10.4 - 12.6	Thermal infrared	80
D	TM	0.45 - 0.52	Visible blue	30
		0.52 - 0.60	Visible green	30
		0.63-0.69	Visible red	30
		0.76-0.90	Near-infrared	30
		1.55-1.75	Middle infrared	30
		2.08-2.35	Middle infrared	30
		10.40-12.50	Thermal infrared	30

APPENDIX-D

Table: D-1 Number of Soil Samples, its Nearest Locations and Soil Series in the Study Area.

Table: D-1

Sample No.	Locations and village codes	Tehsil name	Soil series (Geological Formations)
SS01	082	Chhata	WUL (VOA)
SS02	161	-do-	-do-
SS03	202	-do-	-do-
SS04	054	-do-	-do-
SS05	056	Mathura	-do-
SS06	110	-do-	-do-
SS07	124	-do-	-do-
SS08	136	Chhata	WLL (AOA)
SS09	166	-do-	-do-
SS10	104	Mathura	-do-
SS11	140	-do-	-do-
SS12	154	Mat	EUL (VOA)
SS13	179	-do-	-do-
SS14	243	-do-	-do-
SS15	196	Baldev Sad.	-do-
SS16	129	-do-	-do-
SS17	188	-do-	-do-
SS18	129*	Sadabad	ELL (AOA)
SS19	093	Mat	-do-
SS20	246*	-do-	-do-
SS21	060	Sadabad	-do-
SS22	055	-do-	-do-
SS23	140	Chhata	UL (AOA)
SS24	211	Mathura	-do-
SS25	225*	Sadabad	-do-
SS26	225*	-do-	-do-
SS27	225*	-do-	-do-
SS28	225*	-do-	-do-
SS29	225*	-do-	-do-
SS30	205	Chhata	-do-
SS31	125*	-do-	-do-
SS32	160	Mathura	TYK (T1)
SS33	200	Mat	-do-
SS34	003*	Sadabad	-do-
SS35	019	-do-	-do-
SS36	018*	-do-	-do-
SS37	146	Mathura	YK (FP)
SS38	093	Sadabad	-do-
SS39	158	-do-	KK (RA)

* In Situ Spectral Measurement

Table: D-2 Number of Soil Samples from the Selected Soil Profiles and its Nearest Location in the Study Area.

Table: D-2

Sample No.	Locations and village codes	Tehsil names	Soil series (Geological Formation)
SP01	154	Mat	EUL (VOA)
SP02	243	-do-	-do-
SP03	056	Mathura	WUL (VOA)
SP04	161	-do-	-do-
SP05	093	Mat	ELL (AOA)
SP06	165	Chhata	WLL (AOA)
SP07	104	Mathura	-do-
SP08	211	-do-	UL (AOA)
SP09	225	Sadabad	-do-
SP10	160	Mathura	TYK (T1)
SP11	019	Sadabad	-do-
SP12	146	Mathura	YK (FP)
SP13	158	Sadabad	KK (RA)

Table: D-3 Nutrient Range in soil series

Table: D-3

Soil Series	Nutrient Index (NI) Range (%)		
	N	P	K
EUL	1.8 - 3.4	1.8 - 3.4	3.5 - 4.2
WUL	1.8 - 3.4	1.8 - 3.4	3.5 - 4.2
ELL	1.8 - 3.4	1.8 - 3.4	3.5 - 4.2
WLL	1.8 - 3.4	1.8 - 3.4	2.7 - 4.2
UL	<1.8	1.8 - 2.6	1.8 - 3.4
TYK	<1.8	<1.8	2.7 - 4.2
YK	1.8 - 3.4	1.8 - 3.4	3.5 - 4.2
KK	1.8 - 2.6	1.8 - 2.6	2.7 - 4.2

Table: D-4 Fertility of soil series.

Table: D-4

Soil series	Tehsil name	Macro-Nutrients		
		N	P	K
EUL	Mat	0.08	0.10	1.35
	Sadabad	0.07	0.22	1.31
WUL	Chhata	0.07	0.22	1.27
	Mathura	0.08	0.08	0.56
	Mathura	0.07	0.15	1.42
ELL	Mat	0.05	0.07	1.35
	Sadabad	0.06	0.13	1.20
WLL	Chhata	0.04	0.13	1.49
	Mathura	0.05	0.26	1.63
	Mathura	0.03	0.13	1.56
UL	Chhata	0.01	0.06	1.20
	Mathura	0.02	0.05	1.24
TYK	Mathura	0.04	0.06	1.45
	Sadabad	0.05	0.04	1.20
YK	Mathura	0.03	1.10	1.20
	Sadabad	0.05	0.14	1.27
KK	Sadabad	0.04	0.07	1.20

Table: D-5 Geo-technical characteristics of soils.

Table: D-5

Soil series	Location	Tehsil name	Liquid limit (%)	Flow index (%)	Plastic limit (%)
EUL	Akbarpur	Mat	24.46	12.75	07.28
	Madha Pithu	Sadabad	25.75	04.00	12.42
WUL	Chhata	Chhata	16.00	05.50	11.07
	Pura	Mathura	14.50	11.25	15.38
	Baburi Garvi	Mathura	22.00	07.00	15.20
ELL	Kolahar	Mat	31.25	07.00	11.09
	Hathkauli	Sadabad	26.00	07.00	13.39
WLL	Ajnokh	Chhata	16.00	05.50	10.62
	Tarauli Janubi	Chhata	17.00	08.75	10.68
	Khamini	Mathura	28.50	18.00	15.49
UL	Umraya	Chhata	18.50	09.50	08.39
	Parkhan	Mathura	20.50	04.25	11.26
TYK	Anganpura	Mathura	15.50	08.25	13.49
	Bhim	Mat	17.75	08.50	13.43
	Mahaban-Bangar	Sadabad	16.50	08.00	15.94

APPENDIX-E

Table-E-1 Physical Characteristics of Surface Soils of Different Series

Sl. No.	Soil Series	Nearest location & village code	Tehsil Name	Colour	Mech. Comp. (%)			Moisture (%)	Liquid Limit	Flow Index	Plastic Limit
					Sand	Silt	Clay				
1	WUL	161	CHHATTA	Br-DYB	71.46	07.27	21.27	0.90	16.00	05.50	11.07
2		202	CHHATTA	Br-DYB	49.30	17.20	33.50	2.33	17.00	08.75	10.66
3		125	CHHATTA	YB-DYBr	66.77	23.72	09.35	0.65	16.50	05.60	11.87
4		056	MATHURA	LBr-DBr	78.10	12.54	09.36	3.70	14.50	11.25	15.38
5		110	MATHURA	YBr-DYBr	73.95	06.70	19.35	1.06	13.25	11.07	14.90
6		124	MATHURA	LYBr-DYBr	75.96	11.24	12.80	1.13	13.01	11.16	14.52
7		161	MATHURA	YBr-DBr	77.50	14.14	08.36	0.70	17.25	13.00	13.09
8	WLL	136	CHHATTA	YBr-GrBr	56.73	16.45	26.82	2.28	16.00	05.50	10.62
9		166	CHHATTA	GrBr-DGr	59.10	29.90	11.00	2.00	17.00	08.75	10.68
10		104	MATHURA	LGr-DrGrBr	51.50	35.60	12.90	1.20	28.50	18.00	15.49
11		140	MATHURA	LGr-DGr	50.87	38.63	10.50	1.60	20.50	08.25	13.19
12	EUL	034	MAT	Br-DBr	53.54	18.36	28.10	1.75	23.75	11.67	10.21
13		154	MAT	Br-DrBr	63.70	16.30	20.00	3.70	24.46	12.75	07.28
14		149	MAT	YBr-DrB	58.70	11.20	30.10	2.50	27.19	13.16	12.10
15		249	MAT	YBr-DBr	75.28	09.92	14.80	2.83	26.93	12.82	11.99
16		129	BALDEV	YBr-DYBr	51.10	09.30	39.60	1.05	24.16	11.91	10.56
17		031.	SADABAD	YBr-Br	53.06	13.22	33.72	3.80	26.00	07.00	13.39
18		129	SADABAD	YBr-Br	70.90	15.30	13.80	4.26	25.75	04.00	12.42
19		196	SADABAD	YBr-Br	78.77	07.53	13.70	0.90	25.26	04.89	12.66
20	ELL	093	MAT	LGB-GB	50.60	32.80	16.60	1.45	31.25	07.00	11.09
21		060	SADABAD	G-DGB	51.50	21.40	27.10	6.00	26.00	07.10	13.39
22		160	MATHURA	Br-DBr	66.76	17.19	16.05	1.15	15.50	08.25	13.49
23	TYK	200	MAT	LB-DYB	63.25	25.13	11.62	1.20	17.75	08.50	13.43
24		019	SADABAD	LB-DYB	57.87	30.90	11.23	1.25	16.50	08.00	15.94
25	YK	146	MATHURA	LG-DG	85.00	04.18	10.82	1.53	00.00	00.00	00.00
26		093	SADABAD	LB-GB	42.16	52.34	05.50	2.78	00.00	00.00	00.00
27	KK	158	SADABAD	LG-YB	81.25	10.05	08.70	0.45	00.00	00.00	00.00
28		140	CHHATTA	LG-DB	30.50	32.30	37.20	3.40	18.50	09.50	08.39
29	UL	211	MATHURA	LG-GB	19.58	50.31	30.11	2.90	20.50	04.25	11.26

Table-E-2 Physical Characteristics of Surface Soil Samples Representing the site of Radiometric Measurements

Sl. No.	Nearest location & village code	Mech. Comp. (%)			Moisture (%)	Texture class	Munsell colour designations	Soil s series	Tehsil name
		Sand	Silt	Clay					
1	225A	35.59	26.59	37.82	03.00	C-Loam	10YR 5/3	UL	SADABAD
2	225B	34.92	38.84	26.24	03.09	Loam	2.5Y 5/4-10Y 5/4	UL	SADABAD
3	225C	39.86	32.77	27.37	05.67	C-Loam	2.5Y 5/2-10Y 6/2	UL	SADABAD
4	225D	44.84	29.50	25.66	18.55	Loam	2.5Y 5/4-10YR 5/4	UL	SADABAD
5	225E	42.52	08.84	48.66	18.10	Clay	5Y 5/3, 6/3-2.5Y 5/3	UL	SADABAD
6	125F	67.17	22.92	29.91	12.13	S-Loam	10YR 3/3	UL	CHHATA
7	102G	41.17	31.75	27.08	08.26	Loam	10YR 3/3	UL	CHHATA
8	246H	55.00	32.67	12.33	04.08	S-Loam	10YR 5/4, 6/3	ELL	MAT
9	003I	41.42	28.17	30.41	03.29	C-Loam	10YR 6/4	TYK	SADABAD
10	018J	46.26	43.75	09.99	05.16	Loam	10YR 6/3	YK	SADABAD
11	129K	68.75	22.50	08.75	09.21	S-Loam	10YR 4/6	ELL	SADABAD

Table-E-3 Showing the Chemical Characteristics of Surface Soils of Different Series

Sl. No.	Soil series	Nearest location & village code	Tehsil name	CEC me/100gm	ESP	pH	EC dSm^{-1}	SiO_2 (%)	Al_2O_3 (%)	$NaHCO_3$ (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	Fe_2O_3 (%)	MgO (%)
1	WUL	125	CHHATA	09.70	<15	08.05	00.35	68.98	10.96	02.16	0.36	03.07	1.41	3.00	1.02
2		056	MATHURA	08.25	<15	07.25	00.22	66.91	12.33	01.24	0.70	03.76	1.32	3.96	0.46
3		161	MATHURA	08.65	<15	07.62	00.25	74.37	10.63	01.77	0.46	02.99	1.32	3.90	0.46
4		136	CHHATA	11.42	<15	08.05	00.19	61.32	13.42	02.10	0.54	03.16	1.27	3.74	0.48
5	WLL	166	CHHATA	12.75	<15	08.30	00.18	68.77	09.15	02.30	0.60	03.59	1.16	4.10	0.52
6		104	MATHURA	10.50	<15	07.28	01.22	70.64	12.07	03.10	1.20	03.93	1.05	3.90	0.42
7		140	MATHURA	10.80	<15	08.15	00.20	68.77	12.60	02.16	0.60	03.76	1.20	4.30	0.54
8	EUL	154	MAT	08.12	<15	08.40	00.24	73.95	10.20	02.30	0.46	03.25	1.41	3.24	1.10
9		196	SADABAD	09.80	<15	07.85	00.21	69.60	10.20	02.50	0.91	03.42	0.50	4.81	0.75
10	ELL	093	MAT	11.00	<15	08.40	00.65	62.56	08.72	01.91	0.34	03.25	1.35	3.20	0.65
11		060	SADABAD	14.60	<15	08.06	00.50	55.52	12.89	02.50	0.61	02.90	1.07	3.10	0.61
12	TYK	160	MATHURA	08.25	<15	08.25	00.30	63.39	10.20	01.38	0.28	03.50	1.31	3.84	0.64
13		019	SADABAD	14.30	<15	08.10	00.25	65.25	10.66	02.69	0.20	02.90	0.45	3.21	0.61
14	YK	146	MATHURA	15.50	>15	08.50	00.16	56.14	10.55	02.04	0.47	02.90	5.26	4.10	2.35
15		093	SADABAD	09.50	>15	08.66	00.18	57.79	08.72	01.64	0.63	03.07	3.66	2.71	2.14
16	UL	140	CHHATA	25.50	>15	08.50	14.12	36.46	10.89	05.47	0.30	02.90	1.68	2.64	0.56
17		211	MATHURA	15.50	>15	08.80	05.60	41.27	09.65	02.04	0.24	02.99	2.54	3.60	0.62
18	KK	158	SADABAD	10.20	<15	08.15	00.18	74.78	11.28	02.43	0.39	02.90	0.87	2.80	0.78

Table-E-4 Chemical Characteristics of Surface Soil Samples, Representing the Site of Radiometric Measurements

Sl. No.	Symbols & village code	Effervescence with conc. HCL	pH	EC dSm^{-1}	SAR me/l	$Ca^{++} + Mg^{++}$ me/100gm	Na^{+} me/100gm	K^{+} me/100gm	CO_3^{-} me/l	HCO_3^{-} me/l	Cl^{-} me/l	SO_4^{--} me/l
1	225A	Strong violent	10.50	02.03	71.33	0.29	27.16	0.26	2.31	02.18	00.10	0.002
2	225B	V. strong violent	10.32	01.61	81.13	0.21	26.29	0.21	2.56	10.76	09.20	0.057
3	225C	Weak	10.40	01.92	70.67	0.21	22.90	0.24	0.52	01.80	05.95	0.015
4	225D	V. weak	08.95	15.20	49.37	0.40	16.31	0.52	3.08	03.84	00.20	0.014
5	225E	Weak	09.83	00.42	50.78	0.30	19.67	0.30	3.07	01.80	00.20	0.019
6	125F	V. weak	08.60	10.92	66.04	0.36	28.02	0.40	0.52	04.48	51.95	0.214
7	102G	V. strong	08.22	00.40	54.94	0.26	19.81	0.35	3.08	02.05	59.45	0.170
8	246H	Strong	07.80	18.30	09.14	0.93	06.23	1.26	1.03	02.95	00.30	0.012
9	003I	Slight	07.92	00.21	17.23	0.41	07.80	0.46	1.54	01.80	01.75	0.008
10	018J	V. strong	08.02	00.32	20.80	0.32	08.32	0.59	1.03	02.31	00.43	0.007
11	129K	Weak	08.60	00.33	16.29	0.30	06.31	0.72	2.05	01.54	01.93	0.005

SYMBOLS & ACRONYMS

SYMBOLS AND ACRONYMS

Acronym Expansion

10^{-2}	Decade Factor	**FOV**	Field of View
10^{-3}	Decade Factor	**FP**	Flood Plain
A	Angular	**G**	Grey
A/D	Analogue to Digital	**GB**	Greyish Brown
a.m.s.l.	Above Mean Sea Level	**GCP**	Ground Control Point
AOA	Aligarh Older Alluvium	**GIS**	Geographical Information System
B	Brown	**ht.**	Height
BIL	Band Interleaved by Line	**IFOV**	Instantaneous Field-of-view
CCT	Computer Compatible Tape	**IR**	Infrared
C-loam	Clay-Loam	**IRS**	Indian Remote Sensing Satellite
DB	Dark Brown	**ISRO**	Indian Space Research Organization
DG	Dark Grey	**KK**	Karban Khadar Soil Series
DGB	Dark Greyish Brown	**Lat.**	Latitude
DPS	Data Processing Centre	**L-Sand**	Loam-Sand
DQE	Data Quality Evaluation	**LB**	Light Brown
DYB	Dark Yellowish Brown	**LG**	Light Grey
EC	Electrical Conductivity	**LISS**	Linear Imaging Scanning Sensor
Encrus.	Encrustation	**Long.**	Longitude
ESP	Exchangeable Sodium Percentage		
EUL	Eastern Upland Soil Series		
FCC	False Colour Composite		

MB	Megabytes	**SI-Loam**	Silty-Loam
MBDL	Meter Below Ground Level	**S-Loam**	Sandy-Loam
MBPS	Megabytes per Seconds	**Sodi.**	Sodic
MGE	Modular GIS Environment	**SOI**	Survey of India
MHz	Mega Hertz	**SP**	Soil Profile
MSS	Multi Spectral Sensor	**SS**	Surface Soil Sample
Mt.	Meter	**ST**	Site of Radiometric Measurement from Surface Soil
NB	Narrow Band		
NDC	NRSA Data Centre		
NIC	National Informatic Centre	**T_1**	Terrace Zone
NRSA	National Remote Sensing Agency	**TM**	Thematic Mapper
		TYK	Trans-Yamuna Khadar Soil Series
OIF	Optimum Index Factor		
PCA	Principle Component Analysis	**UL**	Usarland (Salt-affected soil) Soil Series
pH	Hydrogen Ion Concentration	**μm**	Micron Meter
Pixel	Picture element	**USDA**	United State Department of Agriculture
RA	Recent Alluvium		
S	Spheroidal	**VOA**	Varanasi Older Alluvium
SAR	Sodium absorption ratio	**WLL**	Western Lowland Soil Series
S_1	Saline Soil	Y_1, Y_2... Y_9	Yamuna sub-Basins
S_2	Sodic Soil	**YB**	Yellowish Brown
Sc-Loam	Sandy-Clay-Loam	**YK**	Yamuna Khadar Soil Series
SI-clay	Silty-Clay	**SB**	Spectral Band
SIC-Loam	Silty-Clay-Loam		